ERGONOMICS FOR HEALTHCARE PROFESSIONALS

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Table of Content:

Serial	Chapter Title	Pg.N
1	The Role of Physical Environment in Healthcare Delivery **Rishabh Kumar Rana**	1
2	Ergonomics In-Patient Care and Professionalism in Medical Disciplines **Deepankar (PT)**	15
3	Anatomical Aspects of the Musculoskeletal System in Relation to the Ergonomics **Murlimanju B.V,Mangala M. Pai**	19
4	Challenges and Opportunities of Ergonomics and Safety in Healthcare **Amrita Ghosh, Ranabir Pal**	26
5	Ergonomics in Healthcare and Patient Safety **Ranabir Pal, Amrita Ghosh, Debashis Sinha**	43
6	Ergonomics in the Intensive Care Unit **Luis Rafael Moscote-Salazar, Gabriel Alexander Quiñones Ossa**	65
7	Ergonomics, Musculoskeletal Disorders and Patient Handling **María Alejandra Aguilar-Vergara, Hernán David Vergara-Burgos, Ivan David Lozada-Martinez**	72
8	Ergonomics and Neurosurgery- An Introduction **Luis Rafael Moscote-Salazar,Gabriel Alexander Quiñones Ossa**	91
9	Philosophy and Ergonomics of Operating Positions in Microsurgeries **Carmen Sofía Sierra-Ochoa, Sandra Marcela Mass-Ramírez, Ivan David Lozada-Martinez**	102
10	Technological Advances in Current Neurosurgical Ergonomics **Rakesh Mishra, Bhushan D Thombre, Amit Agrawal**	122
11	Robotic Neurosurgery & Ergonomics of a Neurosurgeon **Noor ul Huda Maria,Qurrat ul ain, Dr Aftab Subhani, Noor ul Ain Fatima**	130
12	High-Reliability Organization in Neurotrauma and Neuro emergency Services **Md Moshiur Rahman, Ivan David Lozada-Martinez Sabrina Rahman**	151

13	Ergonomics of Surgical Microscopes **Amit Chakrabarty**	177
14	Ergonomics Interventions in Neurosurgical Devices and Instruments **Rakesh Mishra, Amit Agrawal**	185
15	Ergonomic Equipment Recommendations, Body Mechanics, and Work Simplification Techniques **Vishwaraj K Mhalshekar**	198
16	Recent Advances in Human Factors and Ergonomics in Healthcare Dr. Sonia Nasreen Ahmad **Shaheen Sikder**. **SM Khorshed Mazumder**	210
17	Computer Vision Syndrome an Evolving Condition among Healthcare Workers **Tanvi Poy Raiturcar**	216
18	Gender Based Human Morphological Variations for Ergonomics **Prameela M.D.**	225
19	Safety Culture in Healthcare Delivery Systems **Ravleen Kaur Bakshi, Pankaj B. Shah**	236

Book Description:

Recently there is increasing awareness regarding the ergonomic friendly environment. The book “Ergonomics for Health care Professionals” is proposed to understand the principles and practices of ergonomics for health care professionals and intend to cover different aspects related to professional risk factors.

The book is intended as the study material for the surgeon's, physicians, medical device and technologists, industry partners involved in health care delivery systems and residents for use in clinical practice. The series “Ergonomics for Health care Professionals” contains publications on theory, applications, and design methods of Ergonomics and different aspects of patient care and health professionals. Virtually all disciplines such as engineering, medicine, anaesthesia, infection prevention, trauma and emergency medicine, neurosurgery, natural sciences, computer and information science, healthcare, life science are covered. They cover significant recent developments in the field, both of a foundational and applicable character. An important characteristic feature of the series is the short publication time and worldwide distribution.

Chapter 1

The Role of Physical Environment in Healthcare Delivery

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ABSTRACT

The present chapter uses recent research from 2005 onwards, published on PubMed and other databases, to highlight the importance of impact. The physical environment has on the staff's health, including doctors working inside the hospital building, the effect of the physical environment on attendants who accompany the patients most of the time, and the impact on the patient's health benefits. When we talk about health systems, it does include the health care delivery beneficiaries and the health caregivers. Health is not a single entity but a combined outcome of multifactorial components of which the environment is an integral part. With the rise of chronic diseases, evidence now suggests more emphasis on the building infrastructure, including its aesthetics and upkeep are equally crucial if health is to be delivered at its optimum. Ongoing through the studies, it was found that most of the studies targeted the patient group for their overall outcome while the staff was less explored. The chapter intends to build on these findings and provide a workable way for the reader and policymakers to better the future.

Introduction

First, can you imagine a public health nurse (A.N.M.) working with a crowd of children wailing with hunger in the sweaty month of May under a tree? She is there to immunize the children, and mothers are in a hurry to go back to their homes away from heat and scorching sun. Imagine the nurse giving them the four critical messages as mandated by GoI!!! And picture the same nurse working in a neat corporate-looking setup where only one child is coming to the nurse at a time for Vaccination with their mothers. The room is well lit, and the temp is pleasantly set for a cool 24-degree centigrade. Just imagine the ease with which the same nurse can deliver the four key messages!! The delivery of four key messages which highlights various aspects of immunization like knowledge about the importance, knowledge about the possible health issues post-immunization, knowledge about the correct upkeep of records about immunization, and the proper timing and place for the next immunization dose are an integral part for the success of immunization program in low and middle-income countries. At the same time, they are also crucial in the developed world to address the new menace of vaccine hesitancy. (1,2) The above situation is not an alien one; I am sure many readers must have encountered such problems in the field and some in their corporate hospitals. Imagine a day when all public health setups can have a room temperature set to pleasant sitting temperature and children coming one by one with their mothers without the pangs of hunger, the haste of leaving—owing to the daily loss of wages and the nurse sitting comfortably delivering those four critical messages along with pleasantries.

The physical environment changes human behavior, and human behavior is an essential aspect of the whole health care delivery system, be it the private sector or public sector. Of late, research regarding the importance of communication and physical environment has started, initially based on diseased conditions, which has gradually generated interest in general requirements. (3,4) One of the concerns regarding the communications discrepancies which perhaps started the interest in the published domain is attributed to the fact that most of the latest communications devices are being designed by young individuals. The older generation needs to constantly adapt and learn to use the devices to improve their communication. (5)

Need for effective communication and possible factors

Communication remains an essential aspect of health care delivery systems where it determines who gets what. Patients who can communicate will be better at making their doctors understand the problem they seek for treatment. In contrast, doctors who can communicate with the patients will better foray into positive outcomes with the treatment provided. (6,7) New age science now changes the way patients and doctors interact. As evidence has been emerging, which says a patient-centric communication is not enough. Still, we need to have a two-way communication where both doctor and patients can interact to have a maximum effect (8,9).

When it comes to effective communication, we need to have a look at certain factors, namely emotions, time constraints, expectations that differ, along with aspects related to the social and physical environment (10) It has been time and again highlighted a gap between what doctors and nurses, the primary channels for communications and health delivery personnel, read in theory and what they practice. One of the reasons for this gap is the lack of communication training (11,12). When it comes to better communication, its best approach is a Tailored approach for individuals, which depends on other factors necessary for communication. The physical and social environment in the workplace will always remain an integral part that might decide how your emotion runs, how the time constraints are met, and lastly, how you go about doing things (13,14)

The Physical Environment for effective treatment and recovery

Plans to improve healthcare by enhancing the atmosphere in which patients work and receive treatment have been around for at least the last two centuries with Hippocrates and Sushruta. While Florence Nightingale further propagated and demonstrated the idea to the modern world. (15) Surgeons showed the importance of the physical environment's appropriate importance and its overall impact on health outcomes (16). Once the verdict of Sick Building syndrome was out, as propagated by Burger, things took a more critical turn, and more emphasis was being done on building the structure of health care facilities. (17) With the advancements and more published research, there was a new concept of design solutions in healthcare known as Evidence-Based Design. (18) Evidence-based design (EBD) researched the physical environment and health a new push. More evidence was generated, ultimately giving rise to the term " healing environment," which was defined as "as a place where contact between the patient and the staff creates positive health outcomes in the physical environment." (19, 20, 21). Consecutive research has established the importance of evidence-based design and that EBDs will make healthcare facilities like hospitals less stressful and promote faster treatment for the patients. Also, improve family members' well-being and create a comfortable and safe workplace for the health staff. (22)

The physical environment has been studied in detail and broadly can be classified as

1. External environment and
2. Internal environment.

The external environment is primarily related to the things outside the premises of the building inside the health care facilities. Still, they are visible to patients' eyes, family attendants within the vicinity of the staff. A proven and researched view from an open window is an excellent example to understand the point of contention. (23) Similarly, the internal environment has various components, ranging from the colors of walls to the bed sheet color, the drapes arrangement, and the nursing stations' spatial location. COVID19 also highlighted the importance of the Heating, Ventilation, and Air-conditioning (HVAC) system of the Health care facilities and difficulties in managing the sound levels when it came to the physical environment.（24）Research has been done on hospital interior designs, patient falling, indoor efficiency, comfort, building materials, visual comfort, acoustics, and privacy, with their relationship to healthcare workers' mistakes and acoustics. The same research has addressed the indoor climate（e.g., ambient temperature, humidity, ventilation techniques, and air quality） under the safety and protection subtopics, not patients' medical outcomes.（25）

Below is an illustrated table with the factors known to positively affect and have been researched based on the two primary divisions mentioned above.

Physical Environment（26,27,28,29 ）	Outside the building	Inside the building
	View from the building	Heating Ventilation and Air-conditioning
	Visual Comfort	Identical rooms
	Acoustic Comfort	Lighting
	Orientation	Design of the room
	Plenty of nature around the building	No slippery floors
		Appropriate door openings
		Bed curtains
		Hand washing facility
		Single bedrooms
		Cross Air circulation
		Ventilation, dust, smell, relative humidity, and air quality
		Correct placement of rails and accessories
		Correct toilet and furniture height
		Smooth edges in rooms

Another aspect of the inside of physical environments is a) privacy of the patients either indoor or waiting (30) b) comfort of the patient (31) c) psychologically appropriate artwork has been researched to have a beneficial effect on the healing aspects of patients. (32) d) visual comfort includes daylight factors, luminance, and luminance intensity and their impact on people. (33, 34) e) family support has been studied by various researchers without a clear consensus, having too many visitors have been associated with infections, while it has also been demonstrated that close relatives could help in healing (35,36,37,38)

The above-listed factors have been shown to have beneficial effects on the ultimate impact for the outcomes in any health care facility, i.e., healing of the patient. Apart from the patient benefit aspect, there is the staff also in the health care facilities. Research addressing staff and their environment has been researched less, but evidence points to a better organization like placing signposts in significant intersections. Wayfinding can be an arduous task in all Indian H.C.F.s for patients and with some experience for some staff as well!!! (39)

The concept of Optimal Healing (40)

The concept initially propagated by Sakallaris BR and MacAllister L in 2004 talked about providing an environment encompassing all the features mentioned above. It envisages a system with internal, interpersonal, behavioral, and external components intertwined for the common benefit. Further research on O.H.E. has made it simple in terms of place, people, and processes. The authors for this (41) have advocated more research on various factors. They suggest incorporating these in layout for buildings and governments to listen and include in their planning when new H.C.F.s are being constructed.

Role of Physical Environment in COVID-19

Ever since the advent of COVID-19 optimum healing environment and its importance were highlighted again, as efforts were in place as quickly governments across the nations had to build new infrastructures and hospitals to treat COVID-19.

In these times, social support to the health care providers, including doctors, nurses, staff, and other associates, was more needed than at any other time. (24, 42, 43) Experiences from across the world focused on HVAC solutions and a reduction of infection from one point to another in the management of COVID-19. (24,47, 48) Recommendations for effectively preventing SARS Cov 2 have been more towards having ventilation with more outdoor air with effective airflow. Recommended outdoor air dampers as high as 100% have been suggested, more focus on regular cleaning of the air filters has been emphasized, and have been recommended to have negative pressure in toilets and regular checks for the water seal (48). As the world grappled with a permanent cure, all nonmedical interventions were done, including the lockdowns.

Perhaps the most important of them was the concept, which again highlighted the importance of physical environment being propagated in the form of social distancing where two people are to be at least (49). Governments across the countries understood this concept as social distancing was an integral component in almost all guidelines across the world, and efforts were in place to make the existing structures compliant physically to have that in place. More visual cues were put in place, and people were seen in many areas following them. People were made to understand how important it is to remain distanced from each other in all public places imaginable. Hospitals were researched to see how social distancing has benefitted, including family members and staff (50,51,52).

Indian Scenario and Physical Environment in H.C.W.s

Indian health care has seen a rapid surge in modernity in private sectors where more inclination is towards providing five-star service and an accepted evidence-based medicine treatment regimen. Ever since COVID-19 struck, India's challenges were immense due to its varied culture, customs, schooling rates, topography, and climate diversity. The government of India tried everything from releasing standard guidelines, ads in a prominent newspaper, messages on television and radio to raise awareness and give people the ability to look at everything in their everyday life and maintain their health in the context of COVID-19. Social distancing as an effective preventive measure was used widely by India's government. In villages and even in metropolitan cities like Delhi and Mumbai, congested living areas and unequal access to essential resources are critical challenges for healthy lives.

In India, the standard way of life is not social distancing. Indian societal context involves festivals, rituals, ceremonies, and general meetings. Changes in the social, cultural system are often difficult to accomplish. Research conducted across the country emphasized the need to have a better-designed implementation plan, keeping in mind the various challenges mentioned to create more awareness of COVID-19 and better social distancing. Also, it highlights the importance of the building plans needed to incorporate the concept of optimal healing. (53, 54) . The lessons regarding desired changes in the building concept post COVID-19 perhaps are most evident in India's vaccination guidelines. They have mentioned various structural requirements in the room for immunization and other forms required for safe Vaccination.

An ideal session site should have three rooms: a waiting room, a vaccination room, an observation room with two exit points. Rooms should be well ventilated, with lots of natural air. A well-demarcated area for all rooms has "two gaj" apart from each other. A gaj is roughly 0.91 meters (55)

Before COVID-19 guidelines like RMNCH+A and programs related to catering to the needs of the ever-growing concerns regarding the increasing load of Maternal mortality and infant mortality, the toolkit was highlighting for suggestive building plans primarily inside the health care facilities according to a load of deliveries or caseload of beneficiaries.

This type of construction catering to the specifics of the particular type of patients and load has been advocated as "design thinking". Design thinking prompts more participation from all major stakeholders to be more involved when the buildings are in the planning stage, figuring out the details regarding the physical (56,57).

Way Further

Despite having evidence, we need more research on multiple levels for a comprehensive policy to be followed across nations. Right now, the evidence is scattered majority in developed words and scenarios in L.M.I.C. like ours is slowly coming in terms of emphasis on the Physical Environment as an essential component of the ultimate goal for any H.C.W.s. For example, healing of all patients in a comfortable environment for the family members and safe for the staff working without undue stress.

Time is ripe. We talk about an integrative solution for physical environments in the H.C.F.s, which integrates and imbibes the idea from the above concepts, i.e., the Optimum Healing environment and Design thinking. More research from the Indian scenario will help the country and provide lots of flairs due to the countries' rich diversity in terms of culture and societal customs.

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Chapter 2

Ergonomics In-Patient Care and Professionalism in Medical Disciplines

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ABSTRACT

Ergonomics examines the relationship between human beings and the products they interact with, resulting in improved productivity, creativity, efficiency, job satisfaction, and fewer workplace injuries. The Medical Practitioner needs to be aware of ergonomics' importance and its long-term benefits. Major stress and body fatigue are the common factors which they suffer. Suppose the Medical Professionals understands the principle of ergonomics. In that case, he will most likely be able to treat his patients with a better safe zone because the main purpose of introducing and understanding ergonomics is to improve medical professionals' well-being and performance.

Intoduction

Regular Work Schedules of patients, as well as the medical practitioner, are founded to be hectic. Whether a physician's conditions are concerned or the health of a certified medical assistant or nursing assistant is discussed, both of them do face a lot of body fitness issues. Long working days are generally responsible for fatigue, less productivity in work, and health safety issues. Some studies have also shown that a resident has two possible conditions: rested and non-rested. Resting explains the chronically sleep-deprived whereas the non-rested has some mixed outcome with sleep deprivation like lack of control groups and fewer mitigation factors.

Health Hazards Associated With Work Schedules

When the working hours in a single day increase regularly, it pays up with some common health hazards. These health issues in general consists of the following:

Sciatica

When the herniated disc or a bone spur in the spine applies pressure on the sciatic nerve, inducing unpleasant radiating pain from the lower back to one or both sides of the legs is considered sciatica. The pain here is primarily unilateral.

Frozen shoulder

Adhesive Capsulitis is generally known as frozen shoulder. It is a chronic pain of the shoulder caused due to immobilization of the shoulder joint for a more extended period. Many office workers, physicians, medical assistants are prone to this disease.

Vision syndrome

Vision Syndrome is definitely on the list. Its primary cause is considered to be eye strain. Eye strain can be a symptom to all those who are constantly working with the root canals or work under a path lab.

Neck pain

Many medical practitioners are under the trough of neck pain. Excessive work, all day long with the neck, pulled down or up more than required is the cause for it. Sleeping in the wrong posture or performing wrong neck exercises could also cause neck pain. It can radiate to the forearms or shoulders.

Back pain

Most physicians and medical workers suffer from back pain. It has no underlying diseases. Sitting on the chair for an extended period, uncomfortable sleep, lifting too much weight can be the underlying cause for back pain.

Ergonomic Approach of The Health Hazards Associated To Work Schedules

1. Working hours should be reduced. It is advised to work not more than 12.5 hours in a day and less than 60 hours in a week for a healthy lifestyle.
2. Upright postures are beneficial to avoid back pain and neck pain.
3. Keeping the screen at your eyes' level with a minimum distance of 50-100 I'm will reduce eye-straining.
4. Not more than 3 consecutive night shifts should be allowed to an individual.
5. It is important to take short breaks during a long working day to give your body parts a sense of relief from the strains and fatigue.
6. The employees should be given proper education about how to keep these health hazards away. They should learn to take proper sleep, rotating shifts, and recommended working periods.
7. If the measures are not taken, there is a chance of chronic disease to occur. In such a case, fatigue's underlying root cause should be first understood and eliminated.

Ergonomic Aids in Health Care

The System Engineering Initiative For Patient Safety Model has explained the independence of five major factors that affect an individual's physical health. These five factors are:

Care Provider is providing care by performing a ***task*** using t***ools and technology*** in a given ***environment*** under a specific ***organization***.

The interdependency in an organized way can be achieved if the following measures are taken into account.

1. Arrangement of the working environment
2. Prevention from Health-Care-Acquired-Infection
3. Climate Monitoring
4. Improved air quality and noise control
5. Improved Accessibility towards tasks

Arrangement of the working environment

It is important to have an enhanced safety method to take care of the patients. It is necessary to create a viable space for the operating task while arranging or buying your workplace—enough space aids in the task's success. Easy instrumentation and storage can be allowed if the place is spacious enough.

Prevention from Health-Care-Acquired-Infection

Prevention from the Health Care Acquired Infection is a necessity of every care providing place. It can be achieved by considering the following key points:

- Proper sanitization should be available for both the operator and the patient.
- The use of disinfectants should be compulsory.
- Autoclaving of the instruments should be done before using them on the next arriving patient.
- The patient's medical case history is to be taken before treatment to know what diseases already a patient is suffering from.
- Barriers like face masks, face shields, head caps, eye shields, and gloves should be used before treating a patient.
- Proper Ventilation is a definite measure to be taken.

Climate Monitoring

Moisture control in the place of work is a real factor to consider. Following should be taken care of: Mean Radiant temperature is a meteorological parameter to control the human energy balance. This should be maintained to perform the task efficiently. There is also a need to maintain air velocity and air quality, optimization of humidity levels, controlling activity of the occupants, proper clothing.

Improved air quality and noise control

Air Purifiers should be there in every workplace to control airborne diseases. The air's purification is important not to let the droplets travel and eliminate contagious diseases. When it comes to noise control, it is recommended that silence prevails in medical workplaces. It does not drop out the care provider's concentration and increases the success rate of the tasks being performed. Banners like 'Keep Silence' should be placed as noise can stress the patient.

Improved Accessibility towards tasks

Proper lighting in the workspace increases the Accessibility of the practitioner to provide health services. It can be improved by keeping a check on the luminous intensity and luminous distribution. Perfect Light distribution reduces human errors and improves the care provider's functioning.

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Chapter 3 Anatomical aspects of the musculoskeletal system in relation to the ergonomics

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ABSTRACT

Ergonomics deals with morphology, anthropometry, biomechanics, physiology, and the physical environment. Every individual has a different size and shape, so it is essential to quantitate the body components. This information could be used to scheme the working environment. Repeated body strain from the vibration, force, and posture can lead to pathological changes. The workplace discomfort can lead to pathological changes in the musculoskeletal system. The skeletal muscle constitutes about forty-five percent of the body weight and is considered the most extensive tissue in humans. The human body comprises about 600 skeletal muscles, and each of them is made up of thousands of muscle fibers. Bone can sustain load and bends, but cumulative damage can occur if the load is longer. Joints offer mobility to the musculoskeletal system. In this chapter, a description of the basic anatomy of the musculoskeletal system will be provided.

Introduction

Injuries and low backache among the workers are the primary concerns of occupational safety. The back injury is more significant due to overexertion in the construction workers among males and nurses among females. In North America, work-related back injuries are causing considerable morbidity, physically and economically. Public utility and transportation industries have the highest prevalence of neck, shoulder, and back injuries. Other high-risk people include maids, hairdressers, carpenters, and automobile mechanics. Ergonomics deals with morphology, anthropometry, biomechanics, physiology, and the physical environment. Every individual has a different size and shape, so it is essential to quantitate the body components. This information could be used to scheme the working environment. Repeated body strain from the vibration, force, and posture can lead to pathological changes. In addition, workplace discomfort can lead to pathological changes in the musculoskeletal system. The skeletal muscle constitutes about forty-five percent of the body weight and is considered the most prominent tissue in humans. The human body comprises about 600 skeletal muscles, and each of them is made up of thousands of muscle fibers. Bone can sustain load and bends, but cumulative damage can occur if the load is longer. Joints offer mobility to the musculoskeletal system. In this chapter, a description of the basic anatomy of the musculoskeletal system will be provided.

Anatomical basis of ergonomics

Ergonomics is studying the body's response to physical and physiological work demands. Repeated strain from vibration, force, and posture can lead to pathological changes. Ergonomics deals with anatomy, anthropometry, biomechanics, physiology, and the physical environment. It is essential to study the basic anatomy of the musculoskeletal system to understand ergonomics. The muscular system has three varieties of muscles, skeletal, smooth, and cardiac. The skeletal muscle is voluntary, and the remaining two are involuntary. The cardiac and skeletal muscles are striated. The most extensive tissue in the human body is the striated muscle, which comprises 75% water, and the remaining 25% is made up of proteins and inorganic salts. Production of forces and movements in power require protein molecules and contractile proteins. The human body comprises about 600 skeletal muscles, and each of them is made up of thousands of muscle fibers. Each muscle fiber contains thousands of myofibrils, consisting of muscle proteins, actin, and myosin. The skeletal muscle gets attached to the bone by the collagen fibers, and these tapered endings of collagen fibers are known as tendons. Tendons can transmit the forces from muscles to bones. However, they do not contract.

The musculoskeletal system

Bones

The bones and joints constitute the skeletal system. Like the other body tissues, bones contain cells, fibers, and a ground substance. Bone is a specialized connective tissue, which has more excellent arterial supply and innervation. Bone can respond to stress and injury. The fibers, minerals, and fluids constitute the extracellular matrix of the bone. The collagen delivers the primary structural support to the bone. The bone cells include osteoblasts, osteoclasts, and osteocytes. Among them, osteoblasts are involved in bone formation by secreting the procollagen molecules. The procollagen resists the mechanical stress acting on the bone. The bone matrix contains many minerals and calcium, which provide strength and stiffness to the bone. Osteocytes are the resting cells, which communicate with each other through the bone canaliculi. Osteocytes can either form osteoblast or osteoclast, depending upon the situation.

The bone-forming and removal occur together during the bone remodeling, and these cells are found together. The osteoclast is a bone-removing cell, which is larger than the other bone cells. Osteoclasts have cytoplasmic extensions, which indicate mobility. Bone sustains load and bending, but this is not a permanent change. However, if the load is for a longer duration, cumulative damage can occur. The mechanical stress to the bone will lead to bone remodeling. Stress fractures are due to repeated bone injury and are usually found in the lower limb bones. However, they are also observed in the upper limb bones like radius, ulna, carpal bone, and metacarpal bone. Sometimes, they are because of the external force, like the impact of the calcaneus bone. However, this can happen with internal pressure like a muscular contraction.

Joints

The joints are formed by the adjacent bones, which offer movement in the musculoskeletal system. There are three types of joints, synarthrosis, which do not exhibit any indication; the example includes skull bones. Amphiarthrosis allows slight movement, such as vertebrae and diarthrosis, which show a more excellent range of mobility. Examples of diarthrosis include knee, elbow, hip, and shoulder joints. The joints with higher mobility are prone to injuries because they are the least stable. Hyaline cartilage is found in the articular surfaces of these joints. The synovial joint contains synovial fluid, which has a protein hyaluronate, which provides lubrication. The amount of synovial fluid depends upon the forces acting over the joint. The quantity of synovial fluid decreases during the movement of the joint. During the immobilization, water enters from the cartilage into the joint cavity, leading to a small amount of edema over the common. The joints have specific properties, which prevent friction and facilitates movement.

Vertebral column and lower lumbar region

The vertebral column consists of 33 vertebrae, intervertebral discs, and ligaments. About 1/3rd of the length of the vertebral column is provided by the vertebral column. The disc has a central nucleus pulposus, peripheral annulus fibrosus, and vertebral endplates. The intervertebral disc is made up of fibrous cartilage and is avascular. The nucleus pulposus is a remnant of the notochord, and the fluid pressure within it pushes the peripheral annulus fibrosus and endplates during the intervertebral disc prolapse. The compressive load can cause pathological disc bulging and may compress the spinal nerve roots causing backache. It is also described that bending and torsion injuries are more severe than compression.

Erector spinal muscles support the lower back by flexing and extending the hip during the forward, backward, and lateral movements. The vertebral column facilitates the activities like flexion, extension, lateral bending, and rotation. The active contraction of muscles and passive support by the ligaments control the movement of the vertebral column.

Greater force is required for the erector spinal muscle to keep the body in position; because of the short lever arm of the erector spinal muscles, greater detail is necessary for its action. The abdominal wall muscles decrease the force required to the erector spinal muscle and stabilize the vertebral column. The flexion and extension are best in the thoracic and lumbosacral regions; however, this region has lesser axial rotation. Axial rotation is more significant in the neck than in the lumbar region. Therefore, the compressive strength is smaller in the neck region and increases at the lower level. The power of the vertebral column decreases after middle age. The thoracic cage, which has sternum and 12 ribs, contributes stability and strength to the vertebral column.

Muscles

The skeletal muscle is a contractile tissue, which is often involved in ergonomic injury. There are three varieties of muscles, skinny, smooth, and cardiac. The skeletal muscle is also known as the striated muscle, which is voluntary. The skeletal muscle is involved in various movements like flexion, extension, adduction, abduction, rotation, and circumduction. The skeletal muscle often goes for stress and strain in the workplace. Therefore, topical and oral muscle relaxants are prescribed for the muscle pull. The muscles are also affected in the sports injury, which requires physiotherapy.

Cartilages

Cartilage is a unique variety of connective tissue made up of connective tissue cells, fibers, and matrix. Chondrocytes are the active cartilage cells, and chondroblasts are the stem cells. It contains plenty of elastic and collagen fibers. The intercellular matrix contains proteoglycans, which dictate the property of the cartilage. The cartilage is made up of layers, which helps in withstanding the forces acting on it. The proteoglycans and other proteins maintain the mechanical and lubricating properties of cartilage. The cartilage is avascular and depends on the process of diffusion for nutrition. The absorption and desorption of the fluid facilitate nutrition and excretion. The hyaline, elastic, and fibrous are the three varieties of cartilage.

Ligaments

Ligaments belong to the dense variety of connective tissue, which joins bone to bone. The ligaments provide stability to the bone and passively guide its movement. Sometimes, they are attached to the joint capsule, and many ligaments act together as a single unit. For example, the anterior cruciate ligament assists the tibial and fibular collateral ligaments, thereby preventing the valgus and varus formation. The collagen found in the ligament has cross-links, which further help in resisting the forces. There is a superficial layer of connective tissue, which covers the ligament. This covering contains neurovascular elements, which help in the healing process. The ligament is rich in fibroblasts, which go for a regular turnover. The fibroblasts of ligaments synthesize the collagen fibers; these fibers have wavy patterns to resist the forces acting on them. If the ligament is elongated, the crimped collagen will straighten it, thereby preventing ligament damage.

Tendons

The tendons attach muscle to the bone. It contains connective tissue cells like fibroblasts, collagen fibers, and ground substance. The collagen is manufactured in the ribosomes of the fibroblast. Later it is transported into the extracellular space for further modification. Several collagen fibers are involved in intramolecular and intermolecular cross-linking, which leads to the formation of a singular fibrillar structure. Initially, the links are immature and cannot withstand the larger forces.

Nerves

The peripheral nerve is a bundle of nerve fibers containing specialized connective tissue and blood vessels. The nerve fibers are grouped into fascicles, and the fascicles are found in groups. Each nerve fiber is covered by endoneurium, and the fascicle is covered by perineurium. The epineurium covers the group of fascicles. There are 31 spinal nerves, which originate from the spinal cord–the spinal nerves from cervical, lumbar and sacral plexuses. The neuron is the structural and functional unit of a nerve, which consists of the cell body, dendrites, and axon. The axon carries signals from the cell body, and the dendrites bring alerts towards the cell body. There are several dendrites in a neuron, but there is only a solitary axon. The axoplasm is found inside the axon and has a surrounding membrane known as the myelin sheath. The nodes of Ranvier are located in between the myelin sheaths. The Schwann cells are involved in the myelination of the nervous system.

Anthropometry

Anthropometry involves the measurement of human body dimensions. The dimensions vary from population to population, so it is essential to determine the body dimensions of that particular place. The morphometric data can be used to design the working environment.

The objective of anthropometry is to match the body dimensions of the person with the workstations. This is essential to avoid excessive strain on the musculoskeletal system. For example, a short person with a shorter upper limb should not be advised to extend their forearm to reach an object in a higher place, designed for a taller person with a longer upper limb. Hence, it is essential to prepare the workplace design on a morphometric database, representing the user population in that station. Anthropometry should be flexible, which can house the variety in the human dimension. This is applicable while designing the equipment and work environment.

Anthropologists should create a workplace, which can accommodate 90% of the population. The design of a workstation requires measuring body dimensions like length, width, height, and depth. There are some exceptions, like designing cloth requires measurement of body circumference. There are descriptions by Annis and McConville in 1996 and by Chaffin and Andersson in 1984 about biomechanics. They described the importance of topography of centers of rotation in joints, centers of mass in body segments, link length of inter-joint, and radius of gyration.

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Chapter 4 Challenges and Opportunities of Ergonomics and Safety in Healthcare

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ABSTRACT

In the intersection of the explosion of science and technology, epidemiological transition and rising healthcare sector demand, the researchers anticipate incremental stress on healthcare professionals in a futuristic vision in the new millennium. Further, with the increasing assertion of the patient care algorithms of the healthcare industry, the healthcare providers from primary care to quaternary care are facing ergonomic challenges. In the above situational analysis, the most imperative challenge is to sensitize healthcare personnel regarding the practice of ergonomics and human Factors (EHF) in search of their own wellbeing to ensure safety of the patients. This concept encompasses self-sensitization to identify individual and community risk, uphold compliance and inflexible standards, capacity building in intermingled milieu of cost-benefit and cost-effective models. Aging workforce and aging citizens are upcoming global challenges with increasing expectations of living free of dependency with the perception of 'adding life to years'. 'Work from Home' is the latest challenge of EHF in the 'new normal' situation of unprecedented CoVID-19 pandemic, forcing many to work in restricted set ups with minimal body movements with the logical support of digital revolution (limited to those who can only afford).

Another global challenge is physician burnout 'hidden pandemic' with negative impact on patient safety and quality of care rooted in compromised logistics leading to alarming and avoidable adverse events due to unintended medical errors. These adversely affect by depletion of skilled manpower resources and reduction of safety of healthcare leading to unfathomable economic losses with increasing morbidity, mortality and disabilities. Healthcare management needs to address largely preventable EHF issues that stem in their work environment. Opportunities in ergonomics are vast from research and development in bench-side to translational research in all the levels of the healthcare delivery systems including optimum utilization of spaces. There is an urgent need to optimize safety of both healthcare seekers and healthcare providers by quantitative and qualitative improvements of healthcare paradigms with cultivation of professionalism of stakeholders. User-friendly infrastructure, ergonomically designed medical devices and supportive logistics in unison not only sustain efficiency but also reduce fatigue and mitigate potential shortage of manpower resources for sustainable ergonomics. Creating a culture of safety in the healthcare arena should be a national agenda in the background of EHF logistics is the challenge for sustained global development. Properly combating challenges by creative translational research by interprofessional EHF working groups is the call of the day.

KEYWORDS Ergonomics, safety, patient, healthcare

Introduction

Evolution of the scientific discipline of ergonomics dates back to industrial revolution as today's industries optimize health, ergonomic safety and productivity. The ground-breaking EHF paradigm had been incorporating anthropometry, anatomy, physiology, psychology, biometrics and other emerging and re-emerging scientific disciplines regarding healthcare workplace designs to work in unison with working tools. Global consensus framework of EHF internalizes that any type of repetitive inertia of motion or rest in any non-anatomical position / posture across age and gender can stress the human body fundamentals as noted [1]. Documentation of initial observations by different research groups was the foundation stones of knowledge to snowball the growth and development of EHF science and technology. In the seventeenth century, Italian scholar Bernardino Ramazzini systematically documented the relationship between the occupations and the Work-Related Musculoskeletal Disorders (WRMSDs). He postulated these to have originated from weird harm / hazards / risk factors viz. prolonged stationary / unnatural postures among bakers, writers, weavers; workmen standing / sitting for unusual / longer hours; strenuous muscular activities (c.f. porters/woodworkers/miners) [2]. Lillian et al analyzed the motions involved in brick-laying to find ways to reduce the steps and increase the number of bricks laid per hour to promote cost-effective human labor [3]. In the last decade of the nineteenth century, Taylor et al in the United States conducted critical analysis on time-motion studies used by workmen in performing the varied / specific activities. They had hypotheses to optimize productivity with better pay and improved working conditions which was published in the ground-breaking book 'The Principles of Scientific Management'. The modern office system emerged during the last part of the nineteenth century using the iron laid structures, elevators, lighting, telephone; use of typewriter with filing and use of carbon paper were initial models of the information technology.

Longer office hours produced more backaches with obvious demands for introduction of EHF for white-collar professionals of those days. Two world wars implicated innovative / complex / expensive ammunition with considerable instrumentation to be run with critical human multitasking in lingerie sitting / standing jobs for uncountable hours leading to unexpected mishaps. These costly experiences forced stakeholders to put into practice EHF logical analysis to save lives and tools used to be triumphant in remote locations. These fundamental ergonomic principles of science and technology were later resourcefully transferred to make the manufacturing industry more cost-efficient. Thus radical redesigning of tools and procedures were meant for profiteering, the well-being and breather to the workforces usually took a backseat, though offered marginally higher wages. Later on comfortable working conditions were anticipated by applying ergonomic principles during repurposing from productions of ammunition to consumer goods industries. The great success of pro-people designs led to ongoing interests and interprofessional practitioners formed an association of ergonomics1949 in the UK as the foundation stone of ergonomics [1].

Overview

Since the middle of last century EHF emerged as the scientific discipline with growing apprehension to understand intricate relations of the human body with technical equipment for the highest payback from both man and machine. From understanding / experience of human physical and cognitive demands, conceptual frameworks of ergonomics were slowly relocated to solve disharmony of people and equipment to minimize human errors in the 'human-machine systems'. Collaborative interprofessional research approaches of civilian and military anthropologist, physiologist, psychologist and others revived vista of research studies on interactions of man and machine with the work environment; extended to design of consumer products viz. automobile, computers to suit human capacity. In 1949, the term ergonomics was coined from Greek roots (ergon and nomos) and world's first professional body on ergonomics was formed - Ergonomics Research Society (ERS) to represent the discipline; later relabeled Ergonomics Society (ES) in 1977 for wider focus on professional and practical applications. In the USA the term 'human factors' got a popular synonym of 'ergonomics' in the UK with water-shade in practical usage. The 'human factors' stressed on cognitive surroundings like perception, memory, while ergonomics precisely referred to the physical environment like workplace layout, light, heat, noise etc. To solve this impasse, Ergonomics Society metamorphosed into Institute of Ergonomics and Human Factors (IEHF) in 2009 to imbibe both spirits in single taxonomy attached with a Royal Charter to certify professional acumen as 'Chartered Ergonomists and Human Factors Specialists' for the first time in the world [4].

Ergonomics and human factors is thus time-honored as the scientific discipline combining human biology viz. anatomy, physiology, psychology, with basic science viz. engineering, design, architect and statistics. EHF in healthcare ensured that designs should be dedicated to safety of patients and healthcare professionals rather than expecting staff to adjust uncomfortable, stressful or dangerous products, workplace or system. Human attributes like age, gender, size, shape, strength, cognition, ability, experience, endurance, culture, tradition, resilience, and other goals of life were later being optimized with 'safety first' paradigm. In healthcare, the experts of EHF usually work closely with clinicians, nurses, managers and IT professionals to ensure safety of patient care. Further, effective decision making and reduction of harm from stationary and movable equipment in varied clinical settings viz. ambulances, delivering life-saving practices, ambulatory devices etc. was innovated, developed and evaluated by EHF experts [5].

As the academician and researchers in the healthcare field of operation, we should not limit our responsibility with accurate diagnosis and optimum advice to the best of cognition, ability and skill. We have to inculcate our vision beyond 'Koch's postulate (Universal microbial origin of disease)' and 'Magic bullet (Universal pharmacotherapy)' as many adversaries of the human body and mind have altogether different pathogenesis from an array of risk factors and risk correlates. Further, though thousands of medical schools across the world organize teaching-learning health-related problems along with pathogenesis, yet rarely 'Salutogenesis' is un-tasted water for the majority of the learners. The concept of salutogenesis was introduced five decades back in the past century by Aaron Antonovsky to internalize awe of life. He hypothesized possibilities of to halt pathogenesis by opposing convergence and merger of covert and overt influences of socio-demographic-economic-political factors. Conceptually 'salutogenesis' hailed the perpetually overlooked idea of 'Health promotion' that leads us to healthiness by challenging amalgamation of different harm / hazards. EHF principles are based on the philosophy of 'salutogenesis' to help initiation and continuation of wellbeing and safety that we need to champion in different dimensions at healthcare workplaces for healthcare providers and patients [6,7].

Challenges of ergonomics and human factors in healthcare

Footsteps of the global trends of epidemiological, demographic, environmental and social transitions in the healthcare delivery system, we have to find their determinants spread over our micro and macro environments that affect working milieu. There is increased need and demand from the healthcare sector that is putting pressing demand for competency regarding newer applications of science and technologies amid incremental stress of longer working hours for healthcare professionals in the coming decades. History is at the crossroads of the colossal expansion of healthcare and turned into one of the most demanding industries to untold ergonomic issues for the healthcare providers. From primary care to quaternary care, the challenges faced by the healthcare personnel on ground situations is adversely affecting quality of output of patient care and safety of the healthcare environments. All these ultimately have probabilities of depletion of healthcare resources and boils down to the incremental economic losses and rising morbidity, mortality and disabilities among healthcare providers. Healthcare stakeholders need to address ergonomics and human factors (EHF) that stems in their relevant work environments which are largely preventable by initiating remedial apposite actions for the long-term benefits of the community.

SENSITIZE HEALTHCARE PERSONNEL FOR THEIR OWN HEALTH

In view of above mentioned situational analysis, from the beginning of the professional career all healthcare professionals need to respect their own body with comprehensive self-care practice of safety as of paramount importance. Yet, who will bell the cat to sensitize the healthcare related personnel to sincerely introspect on their own contextual framework of EHF encompassing identification of risks, upholding compliance standards, no-compromise with inflexible quality, continuous updating, capacity building of workplace environments with cost-benefit and cost-effective models to reach the goal of the care and safety of the patient.

AGING WORKFORCE AND AGING CITIZENS

Age is a non-modifiable risk factor as unanimously accepted concept. With the advent of medical science and supportive technologies, more people are actually living in good health with longer life spans. Further with the bursting ability of the healthcare personnel to positively contribute for the society till the seventh decades has been accepted even by the stakeholders in low and middle income countries (LMICs). Qualified and skilled healthcare personnel are working in the tertiary care settings even for longer days up to eighth decade or more when they are engaged in academic activities related with the teach-learning and research works. This is another global challenge of EHF to promote positive productivity with a strong mind from elderly population with their apparent fragile body structure. We need more ergonomically designed tools to champion their increasing expectation of existence free of dependency with our perception of adding life to years.

DOMICILIARY HEALTHCARE – THE UNSEEN PROBLEM

With the explosion of science and technologies newer developments in healthcare is noted every passing day. Firstly, more and more people are living longer at their homely atmosphere with older age in apparently healthy conditions needing supportive care based on health promotion. Secondly, with newer clinical practice guidelines hospital stay is getting shorter during medical care viz. involving more effective drug molecules, non-invasive and/or minimal invasive surgical approaches, rational national and/or international intervention guidelines, early discharge for apprehension of hospital acquired infection etc. Thirdly, persons suffering from many previously incurable/ fatal diseases are living longer with organized and well planned palliative care viz. malignancies diagnosed and treated in early stages, connective tissue disorders, renal and hematological disorders etc. Fourthly, with the advent of science in many situations care and discharge with minimal hospital stay have been parts of guidelines offered by the clinicians, viz. normal delivery; operative cares in a number of specialties like dermatology, ophthalmology, otorhinolaryngology etc.

Fifthly, the spectrum of congenital and acquired neuro-psychiatric disorders is a huge hidden healthcare burden viz. cerebral palsy and/or mental retardation, autism spectrum disorders, genetic and developmental disorders etc. Lastly, in the end-of-life care situations, the caregivers have to help caregivers to put together air-bed, gel-bed, water-bed regarding prevent/minimize/delay and/or treatment of bed sores in bed-ridden persons for numerous reasons from muscular dystrophies in younger generations to inoperable cases of fracture/dislocations in elderly populations.

All these EHF issues provide unaccountable stress to the caregivers at home with mounting as well as never ending frustration and depression 'better said than done'. On the ground situations, the caregivers and patients have a preference to continue part or whole of healthcare management in relatively stress-free homely atmospheres. The patients feel happy to be among their near and dear ones neighbors/ relatives and keep follow-up care periodically that may vary widely on a case to case basis. For these situations transferring patients back home and reporting to the treating healthcare providers on scheduled dates is not smooth with ergonomically designed supportive systems; not easy state-of-affair especially in the LMICs. Further, in their domestic set-ups, the caregivers need the guidance from the EHF trained healthcare personnel/team to procure/organize/re-arrange home environments with modifications with ergonomically designed tools. This is definitely a challenge for us who are planning for the experts and researchers of EHF 'how these should have been sorted out empathetically with cost-effective logistics with options and choices for people of all economic standards' that may change the vistas of individual care over the table.

PROFESSION FROM HOME

With the rapid technological advancements following the electronic revolution initiated from the second half of the past century carried over to this new millennium, there have been sea-changes of outsourcing of work or individual from the main workplace with help of information technology primarily for cost containment as 'telemedicine'. This concept was popularized in the wake of COVID-19 pandemic, when even healthcare workers were pursued to stay at home/clinics with minimal physical contact with patients. With the shutdown of academic institutions, production units, and economic activities, the term 'Work from Home' was coined globally as the latest challenge in the current 'new normal' situation, forcing experts of all specialties to work in limited set ups with minimal movements. New world order has given birth to new nomenclature and taxonomy of healthcare in medical and surgical consultation viz. 'online medical consultation', 'online health consultation', 'tele-health', 'On-Cloud Healthcare Clinic', 'e-health consultancy', 'online teaching' etc. Making homely environments converted to office format within the scarcity of spaces in urban society is definitely a challenge for the EHF professionals [8].

BURNOUT OF HEALTHCARE PROVIDERS

Another global challenge of EHF is the hidden danger of perils for safety from physician burnout rooted in already over-stretched healthcare as a global phenomenon. With chronic and negative impact on the safety and quality of patient care, these compromised situations for the greatest army manpower on earth from the healthcare sector contributes to alarming and avoidable adverse events due to unintended medical errors during discharge of their critical thinking. There is an urgent need for a holistic mental support programme within EHF systems approach of spacing of rest periods with spectrum of stress-busters inbuilt within the job descriptions preparation of schedule of working hours.

HEALTHCARE MANAGEMENT NEEDS A HUMAN FACE

Conventionally management follows an object driven paradigm for the highest output in any production line and the healthcare industry is no exception in both public and private sectors. In the era of exponential growth and application of the newer patient care algorithms on individual care-seekers the healthcare technology is growing more and more sophisticated. The issues of apposite function, manpower allocation / reallocation, modalities of patching / covering up errors, and overuse / misuse of automation and mechanization will continue to challenge safety of the patients as well as efficiency of the healthcare delivery system. In futuristic vision, the management principles should incorporate EHF as an indispensable component to combat the increasing demand for reclaiming manpower potential within the visualization of their weird profit-making spree.

CHALLENGES FOR THE COGNITIVE ERGONOMICS:

There is exigency to understand human interaction with these psychological and mental components to internalize EHF. The invaluable multifaceted automation of cerebral cortex gifted by nature to human existence helped them grow as supreme civilized animal with both intellect and emotions as noted: firstly, the implications of self-organizing by human factors as the challenge of supervising multi-tasking automation with powerful adaptive behaviors; secondly, human interaction with newfound complex computerization by comprehensive analysis and modeling modus operandi; thirdly, reconsidering new constructs to explain behaviour of processing information by inductive and deductive reasoning; fourthly, deep understanding of the competency and skill beyond pedagogy and andragogy of human behaviour beyond a task-based description; lastly, cultivation and nurturing of paradigm of participatory leadership from grass-roots upwards and free-thinking of the healthcare staffs can reap better harvest in the long run.

CHALLENGES FOR THE PHYSICAL ERGONOMICS:

Globally there is accepted wisdom on immense loss to the affected workforce in public and private sectors, in high-income as well as low and middle income countries at large regarding work related diseases in absence of applications of

EHF principles. This critical attributable fraction / component of hazards from the healthcare physical factors grow in snowball effects if not nipped in bud. With strong vision of empathetic global proponents of EHF to ensure safe workplace, zero tolerance should be for the initiation and continuation of these illnesses which add substantial burden without internalizing these risks for individuals. Most of the works in the healthcare professions require common postures in different combinations of rest and motions viz. sitting, standing, and bending forward, flexion and extension of muscles of the head, neck, face, trunk and limbs in different permutations and combinations. Despite years spent on ergonomics research, WRMSDs are still considered as the major problem faced across occupational workplaces especially from lack of attention to EHF compliance in infrastructural design and healthcare is one the most neglected chapters. There is a need to delineate the healthy anatomical posture for every procedure to reduce muscle fatigue with or without generation of pain in the spine or other joint by balanced transfer of stress from smaller to bigger joints / muscles and vice-versa.

WRMSDs decrease efficiency and productivity in multifaceted ways by plummeting work quality in manpower-intensive healthcare; affect from head to foot though commonly noted among sedentary persons. Those with longer hours of spending in common postures complain more of the WRMSDs like sprains/strains, inflammation of the bigger joints, low back pain, and nerve compression syndromes. All the healthcare professionals have to spare some time to introspect in their respective workplace to identify the range of risk factors that may contribute to the development of work related WRMSDs. For example nursing personnel may suggest 'how to reduce of whole range of manual patient handling tasks' and 'demarcate watershed of EHF and patient safety', 'work practice controls to reduce risk of ergonomic injury during patient care', 'change posture frequently consciously without hampering patient care; while public health engineers may have to learn basics of engineering practice and administrative controls to implement EHF principles for the patient safety [9].

Opportunities of ergonomics and human factors in healthcare

Opportunities of implementation of EHF values are unfathomable from observation of health issues through the research and development from the bench-side to translational researches ranging from primary to tertiary levels of the healthcare delivery systems. We have to put efforts to optimize safety of both healthcare seekers and healthcare providers by quantitative and qualitative improvements with user-friendly infrastructure, ergonomically designed medical devices, supportive logistics and capacity building. This will amalgamate with the cultivation of professionalism of healthcare providers in unison to sustain efficiency and efficacy of the system with reduced fatigue and burnout. There is a need for a futuristic vision to mitigate potential shortage of manpower resources for sustainable national health development by creating a culture of safety amid EHF logistics as opportunities in coming decades. We shall take every opportunity to properly combat EHF challenges by exploring passionate movements of the younger generation from interprofessional working groups to implement the fullest EHF potential.

RESEARCH AND DEVELOPMENT

Nothing happens in this world by accident – this is the basis of the beginning of all scientific observations followed by inductive and deductive hypotheses in this world by great people since time immemorial. Research is the eternal journey toward the 'Unknown Truth'. We have to internalize from our basic knowledge of human anatomy, physiology and Biochemistry that we need health promotion to undertake measures from the dimensions of ergonomics and human factors. Further, all the research and development is part of learning in science and technology that poses challenges to clinicians as ergonomically designed infrastructure may not be readily available to suit the needs of their patients at hospital or domestic environments. EHF ways and means may require investigation to determine which approaches are truly dedicated to the safety of healthcare. The ergonomic environmental themes could include reduction of technologies that are inherently harmful, while the ergonomic socio-demographic themes might include that seek to provide safe working conditions or socio-economic themes identify / target areas with scopes / opportunities in underserved areas. Ergonomic governance themes could include futuristic oversight, positive and negative reinforcements, incentives and disincentives, manpower allocation, and worker-friendly policies.

HEALTH ECONOMICS

WRMSDs from overexertion repeated / heavy works viz. push / pull are the costliest workplace trauma with huge financial burden especially in the manual handling areas of healthcare. Scientists have estimated that 460 USD for each worker if these can be kept at a good enough level. Economics of Ergonomics Guide have been developed by Darcor who illustrated economic harms associated with workplace injuries viz. financial risks, methods of assessments and reduction with proactive ergonomics programs including a) critical relation of overexertion with manual handling, b) true estimated cost of overexertion, c) causes of overexertion injuries, d) assessment and reduction of risks, e) assess and test safe levels of cart design, maintenance and movement [10].

HOSPITAL ERGONOMICS AND HUMAN SAFETY:

A range of major ergonomic stressors in the hospital settings to harm include handling and awkward postures with periodic re-evaluation sights as the call of the day. To mitigate these stressors, patient / material handling has to be streamlined for all levels of hospital staff to save them from stress and strain, tears of muscle, ligament, joint, tendon, nerves while handling, transferring, and positioning of patients or materials. Occupational Safety and Health Administration (OSHA) under the aegis of the United States Department of Labour recommended how to minimize / eliminate manual lifting of patients; use of proper assist devices / equipment viz. mechanical lift equipment, shower chairs, sliding boards, gait belts, lateral transfer devices, wheelchairs, repositioning tools, etc. Further, awkward postures are experienced by almost every level of healthcare providers viz. twisted / hyper-flexed / hyper-extended positions / reaching or lateral / side bending increase forces on spine / joints leading to muscle / tendon fatigue and/or joint pains. EHF Scientists have recommended how to avoid awkward postures and/or minimizing twist / bend postures and/or using viz. patient lifts, transfer devices, adjustable IV stands, computer workstations etc. along with good housekeeping and spaces for movement and supportive logistics [11].

CLINICAL SAFETY PROGRAMME:

The clinical safety programs promote environments to make free of hazards noted in the clinical environments especially those in all levels of the health care facilities, diagnostic and clinical support services. These areas also require additional application of concepts of EHF over and above obliging special attention to biological hazards for the employees and the patients. Further, all levels of healthcare personnel should have pre-employment EHF training / retraining and periodic drill by augmenting cognitive/affective/psychomotor skills in with paradigm shift to implement EHF basics at every step for patient safety [12].

LABORATORY ERGONOMICS:

Research groups have observed that ergonomic stressors manifest into WRMSDs in the laboratories from static and/or awkward postures and repetitive motions with infrequent rest breaks. For example, while standing at workstation need comfortable anti-fatigue mat and shoes, while seated employ adjustable sitting with back-rest and foot-rest/prop, keeping routine tools within four arm's reach, lesser usable items to arm's reach with good leg and hand space. Further, with due rest to anthropometry, we need to adjust heights of work surface, chair or stool to work effectively while preserving upright position to reduce bending, hunching, forceful twisting, turning, and pinching;

equipment should be the right size/shape/weight; electronic, automated and light touch model is preferable in correctly lighted, ventilated and comfortable environments [13].

NEED TO INCLUDE ERGONOMICS IN HEALTHCARE TEACHING-LEARNING

Current health care capacity building shows dearth of efforts to sensitize learners to the patient centered comprehensive clinical care related with EHF. Across age-gender groups training inclusive of spectrums of conventional diseases in 'Medicine' demands expertise in catering to patient care needs in both acute and chronic illnesses printed in standard textbooks. There is incremental demand of state-of-art health care of outpatients/inpatients facilities whether from the individual patient at the community levels or surrounded by millions of confounders from ecosystems; many are unknown and embedded in the age old healthcare occupations. We have to internalize that these lifelong accumulation socio-economic harms have synchronous impacts from initiation to closing stages in the natural history of many chronic diseases. So, with dedicated training, the healthcare providers may be able to identify these morbidities earlier with prompt interventions with a high index of suspicion of ergonomic and human factors in the pathogenesis.

The Directorate General of the Factory Advice Service and the Labour Institutes (DGFASLI) were established in 1945 in India to act as the advisor to the Union and the State Governments with the Institutes as follows: Headquarters and Central Labour Institute at Mumbai, Regional Labour Institutes at Chennai, Kanpur, Kolkata, and Faridabad. The mandate of the Central Labour Institute, Industrial Medicine division is to prevent and contain workplace health hazards and occupational diseases, surveillance, prevent and control of health hazards. Industrial Physiology division lay emphasis on research and development, and consultancy services in Occupational Physiology and Ergonomics with a view to improving working conditions; suggest work station design and workplace environments viz. occupational stress, industrial ergonomics; assess and evaluate the nature of work, working conditions and work organization by multi-disciplinary research studies and training programs for better management of human resources to ensure safety, health and welfare and promote cooperation; Fellowship and Certificate courses are offered.

There are different organizations working in the Occupational Health and Safety field in the world altogether. Occupational Safety and Health Administration (OSHA) is a regulatory and compliance body of health and safety in the United States which offers awareness programmes regarding different types of jobs / workplaces. Trainers are also encouraged to spread these knowledge components on safety and health as an Outreach Training Program and without OSHA's involvement as Outreach Training Program.

National Examination Board in Occupational Health and Safety (NEBOSH), UK-based independent examination board offer vocational qualifications in health, safety & environmental practice and management. NEBOSH develops curriculum for qualifications and assessment methods of coursework for globally recognized qualification in Health Safety and Environment to understand health and safety principles and practices.

Institution of Occupational Safety and Health (IOSH) is the Chartered body for health and safety professionals; world leader in health and safety training each year more than one lakh get trained in intensive three day courses to develop practical safe systems of work for non-health and safety expert personnel [14].

SUSTAINABLE ERGONOMICS

Ergonomics evolved with the documentation and flourished with critical thinking on human factors. As part of learning like other branches of science and metamorphosed into the art of intermingling aspirations of the human soul with limbs. Within the framework of scientific approaches, in these ground situations the EHF is dedicated for the direct human welfare and patient safety while utilizing human energy in the most sustainable way. Implementations of effective EHF processes entails prevention and promotion for the general improvement of productivity along with reduction of ergonomic risks in existing operations and ensure ergonomics acceptability of the newer tools. Success of ergonomic upgrading denotes four steps viz. identify probable ergonomics harms, ergonomics evaluation tools, controlling risks and cost justifying reducing risk with job metamorphosis for easier, effective and less painful. These proven EHF applications need to be tried in different settings by proactive researchers and managers of healthcare for best utilization of human factors and safety of patients. Following initial success stories in the healthcare establishments on the EHF, we need to sustain the improvements and explore newer avenues for long-term impacts for the highest safety of both healthcare providers and healthcare seekers. By systematically screening with the formation of a checklist of common as well as specific EHF issues of all the healthcare workplaces, we have to plan for optimum utilization of our resources with the tailor-made solutions [15].

TARGET THE HEART, MIND WILL FOLLOW

Life as the learning process, teaches us to be critical to one, to be honest and sincere in telling a spade a spade, to be happy sharing genuinely and honestly justify our actions. It is an accepted notion that knowledge, skills, attitude, and behavior of the healthcare providers can prevent and reduce morbidity and mortality. What we need to internalize is that 'Ergonomic is an un-tasted water' even for highly educated persons and researchers in the healthcare sector.

Till date, healthcare teaching-learning concentrated on biomedical aspects to unearth the pros and cons of the 'Koch's postulates' and ran in search of 'Magic bullets' to find pharmacopoeial solutions to all problems on earth. But life flows beyond the bench of conventional biomedical laboratories to the bio-psycho-social arena. Millions of healthcare staff along with billions of global workforces across thousands of occupations are suffering from EHF related health issues from compromised situations with age-odd tools and cumbersome logistics. Without knowing that there is a comprehensive healthcare solution to every problem of EHF from primordial to quaternary prevention with special emphasis on promotion of health of the precious healthcare forces for optimum productivity for a longer period of years with a healthline.

An eternal unanswered question arises in healthcare parlance – Whether ergonomics issues are part of the 'Man-made disaster' of whole civilization stemming from greed of profit with little or no attention to safety and health of workmen?' Unfortunately four hundred years have passed since Bernardino Ramazzini documented his recommendations to locate ergonomic health issues from repetitive motions and manual lifting with scientific moderation to improve quality and quantity of hard works that involve standing position or rigorous muscular effort.

Conclusion

Most difficult action in this world is to change ourselves in the ever changing world. If we are unable to transform our workplace environments in the light of vast knowledge of EHF, we will have to face all the health related consequences. We have to take responsibility for our decisions if we fail to address adequate solutions to the EHF hazards in the healthcare workplaces. There is unquestionably a hope as healthcare providers have been gradually showing adequate sensitivity on the positive aspects of EHF in the practice of healthcare delivery and patient safety.

We need to think that there are challenges as well opportunities in EHF to meet the continuously increasing public expectations and demands on patient safety. We have to continue our efforts to find solutions as an ongoing process for which interprofessional research groups will have to play cohesively with public health stakeholders like the public health system; policy makers, researchers and program managers will convert these challenges into opportunities.

They will feel that we always can improve with our will and a practice can always improve the quality of translational health research. Time has come that we have to internalize urgency to assess work related environmental risk factors and risk correlates by participatory contribution in EHF research. The healthcare fraternity has to raise our voice with tailor-made interventions associated with the occurrence of occupational morbidities from ergonomics and safety issues at all levels of healthcare from primary to tertiary levels. Moreover, we need to promote gender diversity and reduce gender discrimination with special emphasis on third gender as mainstream while improving EHF in all the occupational environments. The differentiated and fragmented insights from the workmen should be encouraged for their growth and involvements by encouraging their participatory contribution with futuristic vision.

We should have insights regarding the prevalence of these conditions and broaden the scope for prevention and therapeutic interventions of risk of WRMSDs. Cognitive and physical ergonomics has to be synergistically ensured at all levels of healthcare activities. EHF of healthcare seeks to change everything to match human capabilities, limitations and needs of people by applying all the sciences to the world as universal responsibility and exploring billions of prospects at the healthcare arena with patient safety as central theme.

Eyes cannot see anything that the mind doesn't know – Ergonomics and Human Factors need to be imbibed within.

Key points

1. Ergonomics and human factors should be sensitized
2. Ergonomics as part of healthcare safety
3. Capacity building in ergonomics should be priority
4. Provision of ergonomically agreeable infrastructure
5. ognitive ergonomics must be explored along with physical ergonomics

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Chapter 5

Ergonomics in Healthcare and Patient Safety

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ABSTRACT

Healthcare delivery is conglomeration of pedagogy and andragogy of academic training, the user-friendly logistics and infrastructures, problem-solving skills from womb to tomb, and emergency response reflexes with the mindset of a life-long learner. The spectral role of ergonomics at every step in mitigation of safety of patients, whether in domiciliary level or hospital care, is of paramount importance in the healthcare arena for the wellbeing of citizens in disease and health. From primary level comprehensive care to the quaternary health care, from community level beginning-of-life to domiciliary end-of-life palliative care, the human body should be considered as a living machine for locomotion. The forecast of steady increase of care-seekers of upcoming decades in the face of lag in qualitative and quantitative increment of human resources subtly adds importance to ergonomics for the optimal outcome of range of interventions. Cumulative effects from exposure to risk factors of wrong positional practice grow exponentially through fatigue, discomfort, pain, injury to disability and loss of manpower resources. These stems from longer duration of continued and repetitive work schedule to updating and accommodating with newer gadgets and logistics; horizontal and vertical integration of the algorithms of national and international healthcare programmes add further exhaustion of already over-stretched healthcare infrastructure and manpower. The application of the principles of the ergonomics and human factors (EHF) in healthcare and patient safety means integration of tasks of patient care and amalgamate equipment to fit the healthcare providers minimizing the risk of injury. The health care facilities have to be remodeled from risk-prone areas due to the variable nature of the workplaces and ergonomic stressors impacting the manpower. Target will be to minimize costs, optimum turnover rate, increased healthy working days, and sort optimum utilization in a scientific manner. Further, with the mindset of patient safety, interventions have to focus on kinetics and kinematics of our wonderful human body. This introductory chapter of the book of ergonomics targets to sensitize all levels of healthcare practitioners to help them internalize the conceptual and contextual framework of the safety principles as applicable to the variety of workplace settings. Practice of EHF and safety in the healthcare arena decreases psychosomatic injuries of all forms in all parts of the living tissue-organ-system along with increment of quality and quantity of productivity.

KEYWORDS Ergonomics, safety, patient, healthcare

Introduction

Healthcare is a noble profession intermingled with the Hippocratic Oath and professional approach of 'Lifelong learning' and usually they do not get time to take care of themselves. So there is a need to help internalize all healthcare related personnel to truthfully introspect on the ergonomics and human factors (EHF) on all facets of their workplace environments from primary care to tertiary care levels. This should initiate from the dedicated time to recognize harm and innovative self-actualization on possible harm reduction practices amid keeping conformity with the nonflexible values. The historical task of healthcare providers to identify missing links to be identified for all levels of healthcare are pre-employment capacity building and periodic updating, updating/modifications of the workstations with cost-benefit and cost-effective modeling, holistic search of EHF of both care-givers and care-seekers.

Healthcare delivery include areas are not limited to quality of care and patient safety, but include health economics, health policy, health services, clinical ethics, clinical risk, management of health facilities, health data, healthcare informatics, nursing care, clinical services, out-patients and inpatients care, insurance, accreditation and public health. Thus healthcare is a unique combination of personalized labor intensive care. Further, caregivers have to accept the philosophy of the lifelong learner by the capacity building, problem-solving skills from womb to tomb in line with ever expanding logistics and infrastructures, and crisis management by ready retrieval of cognition and competency.

There is a dire need to accept and collaborate with the backdrop role of ergonomics at every step of healthcare to optimize safety of care seekers. From the pre-hospital set up to hospital-based care safety is of paramount importance in the healthcare arena for the welfare of populace in health and disease; from primary level comprehensive care at the doorstep/courtyard to the tertiary level 'White Elephant' care, from community level/beginning-of-life to domiciliary level/end-of-life care, human body should be considered as living machine for locomotion.

Overview

Experts have deep skepticism regarding the pace of huge demands of human resources in global healthcare arena; need to close doors of our lust for quaternary health care that entails overdiagnosis and overtreatment with minimal benefit of the patients in the milieu of their projectile steady increase in the coming days. This scarcity of healthcare workforce has been subtly adding stress on the importance of ergonomically designed workplace and patient care equipment for the most favorable outcome of case management.

In the long run the snowballing effects from erroneous practice in universal space and time will human body will boil down to psycho-somatic fatigue, uneasiness, distress, musculo-skeletal and other injuries to temporary and permanent disabilities; there will be exponential loss of trained manpower resources from prolonged stressful work environments. Further, demand of occupation to be acquainted and skilled with newer gadgets and logistics; 360^0 intramural integration along with national and international collaborative healthcare paradigms add further fatigue. Aging a healthy population at the healthcare premises is a universal challenge with mounting expectation of improvements of 'Activities of daily living' and life free of dependency. Healthcare providers with the perception of adding life to years are working all over the world at advanced ages to contribute true productivity with a strong mindset. EHF should support more ergonomically designed tools to help fulfill the firm commitment of this older generation for society to work better within apparent fragile body structure. Here lies the role of 'human face' in the face of aggressive upgradation of infrastructures, tools and logistics to comply with 'limited' human factors for ergonomic capabilities so that the multitasking schedules of the healthcare delivery system of the days to come.

Concepts of health and disease in relation to ergonomics

The World Health Organization defined "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. The enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition" [1]. In absence of a universally accepted definition, scientists have expressed their concern to define disease/morbidity/illness/ailments/disorders over the ages viz. "a type of internal state which is either an impairment of normal functional ability – that is, a reduction of one or more functional abilities below typical efficiency – or a limitation on functional ability caused by environmental agents" or "a state that places individuals at increased risk of adverse consequences" [2]. Thus we need to visualize the natural history of occupational disease as a feature film that originates from workplaces due to various harmful factors including ergonomically faulty designed workplaces and conclude at the physician's desk. It is generally noted that the workplace conditions generate numerous psycho-social stress and can negatively affect with psychosomatic manifestations involving almost all tissues-organs-systems in human body in some way or others; may be overt or coverts and unless judged with a high index of suspicion occupational diseases usually goes out of our vision.

Ergonomics and safety issues (the science of work) is defined by the International Ergonomics Association: "Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance (ratified by the IEA Council, 2000)." [3].The term originated from the Greek vocabulary 'ergon' (work or labor) and 'nomos' (natural laws) was coined in 1857 by the Polish scientist Wojciech Jastrzębowski and was a popular term in 1997. Later on interchangeable terms 'ergonomics' meant for physical environment viz. workstations, while in the United States the term 'human factors' got a popular synonym of 'ergonomics' of the UK with water-shade in practical usage in relation to wider human components. The concept of human factors started to focus the mindset of individual workman and psycho-social aspects as well as the cognitive environment like perception, memory, while ergonomics precisely referred to the physical environment like workplace environments considering human anatomy and physiology in relation to the overall layout, ambience, light, heat, noise etc. To solve this impasse, ES was renamed the Institute of Ergonomics and Human Factors (IEHF) in 2009 to imbibe both spirits in single taxonomy with a Royal Charter to certify professional acumen as 'Chartered Ergonomists and Human Factors Specialists' first time in the world history. The concept of safety is being highlighted after the historical merger of these two nomenclatures into single classified scientific discipline as 'Ergonomics and Human Factors' as the safety of humans is portrayed as of paramount importance whether care-seekers or care-givers. IEA and ILO jointly launched 'Ergonomics Checkpoints' in 1996 with easy-to-understand illustrations to improve occupational health [4].

Research groups, experts and consultants feel that 'Ergonomics' is a science-based interprofessional outlook that encompasses and imbibes cognitive, affirmative and psychomotor skills from all other branches of basic and applied science, art, humanities, commerce and management subjects viz. anatomy, physiology, biochemistry, psychology, engineering, statistics etc. Ergonomics and Human factors (EHF) attempt to ensure that the psycho-somatic effort of the average human body should have been used within the limitations of comfort zones for the best outcomes of the development of science and technology using human labor. EHF designs of all the workplace infrastructure, tools and logistics thus complement the strengths and abilities of individuals and minimize the negative effects of their exhaustion at workplaces. Moreover, research groups and specialists of ergonomics and human factors specialists have done paradigm shift to revert their conventional idea to seek to understand how the workmen can be trained to suit tool, product, workplace, infrastructure i.e. the system expecting people to adjust to who need to use it; rather new idea expects than the system have to be optimally EHF designed with dedicated programming to suit/adapt earmarked people to a design that allow them to work in an highly comfortable non-threatening environment.

To reach this goal, EHF experts need to comprehend and design for the variability of endurance distributed in the specific population in healthcare workplaces spanning basic attributes as age, gender, shape, size, power, cognitive ability, ethnicity, experience, expectations and goals of life to optimize performance, safety and comfort in the futuristic vision. The lack of EHF non-complied design can be incredibly frustrating for the healthcare providers who have to pursue long hours of variable activities. Thus EHF professionals need to work in affiliation with healthcare providers, managers and IT specialists to ensure a safe and resilient healthcare system in the new millennium with timely updating as the call of the day. With focus placed on improving EHF, the inter- and intra-discipline communications with the team approach of healthcare professionals to work better to make effective decisions for reduction of the likelihood of harm at respective workplaces. In addition to this collation and collaboration, rejoinder of many pieces of synchronous activities that we find in the pre-hospital and hospital clinical setting, from ambulances, to drips that deliver life-saving drugs, have been developed and evaluated by EHF experts for best possible safety of human lives and limbs with human face in mind.

Sickness from Ergonomic risk factors faced by healthcare workers

Researchers and professionals working in the field of healthcare safety feel that the spectrums of EHF hazards at the healthcare conglomerates are grossly under-reported. There is a need for provision of holistic care to individuals and communities in general in health and diseases, directly or indirectly, denotes healthcare services. These are discharged in various pre-hospital and hospital care outpatients and inpatients settings depending on the levels of the healthcare viz. hospitals, clinics, offices, immunization, day-care, out-patient surgical units, obstetric cares, emergency and trauma care, burn units, detoxification centers, domiciliary care, and nursing care. Healthcare workers face a number of serious safety and health hazards including EHF hazards from lifting, awkward postures and repetitive tasks, burnout, workplace violence among others. The largest numbers of Work-related musculoskeletal disorders (WRMSDs) of all occupations were in nursing assistants with incident cases of 166.3 per 10,000 workers (c.f. 30.5 overall for workers). In addition to the medical care personnel, big healthcare establishments recruit extensive varieties of jobs that have implications on the safety of patients and healthcare providers by prevention of variable health and safety hazards. These include electrical and mechanical maintenance, medical and electronic equipment maintenance, plumbing and housekeeping, dietary services, construction maintenance, laundry and central sterile store department, and administrative staff dealing with computers and documentation of local, national and international importance and supportive and security staff. [5].

There is a need to reduce healthcare workplace harms through the comprehensive, proactive safety and healthcare management system in the most positive ways and means for the preservation of safety of patients and staff; also space saver in EHF paradigm. These collaborative processes will attempt to find and fix the concept of EHF providers to protect healthcare workmen, save money, and promote dedicated effective hazard-specific interventions. In healthcare it is a proven fact that if we prioritize safety in the healthcare environment, we can definitely reap vital supplementary benefits through improved patient safety in the midst of improvement of quality of care. Foremost global healthcare institutions and vendors of automatic/semi automatic instruments have successfully implemented these safety and healthcare management systems in the different forms to limit high rates of non-fatal injuries and ailments which made the healthcare personnel away from patient care interactions. Comprehensive safe patient handling programs (CSPHP) have effects on reduction of WRMSDs and other injuries for healthcare personnel without compromising care of the care-seeker clients on ground situations. Plans to develop or refine any form of CSPHP shield both staff and patients in the healthcare workstations we need to collate the right data at the right time from the right source with the right evidence with the right examples and right interventions. OSHA is promoting a series of online EHF resources to help build up and put into practice safe patient handling policy, procedure, programme, assessment, training, and patient education as well as capacity building at all levels with periodic updating parallel to development of science and technology [5].

The most common illness reported from almost all the workplaces are the WRMSDs especially pains from spine and back muscles hypothesized to have originated from longer spells of working schedules in permutation and combinations of standing/ sitting/ bending/ squatting or any other awkward postures. Supplementary office work schedules in addition to the routine duties may have been influencing the fatigue factors as the significant stressors in white-collar professional personnel who usually practice a sedentary way of life. However, universal risk factors are a) *repetitive task*: high task repetition combined with awkward postures are commonest harms - need provision of safe and effective systems approach viz. task completion with pre-employment training and retraining, rotation amid jobs/workstations, period of rest with stretching spaces; b) *forceful exertion*: minimized with optimum deployments of mechanical/powered assists, counter-balance, adjustable workstation heights, sliding on wheels instead of carry/lift, stress-busters by on-job capacity building and updating to learn/conversant how to reduce muscular effort; c) *awkward posture*: eliminated and/or reduced uneasy/uncomfortable postures that put futile stress/strains on tissues/muscles/tendons/joints to optimize mid-range motion positions / postures for best possible outcomes supplemented with job rotation / task amplification reduce effects from any form of repeated/sustained awkward postures [6].

The healthcare providers face routine physical hazards from various work environments are generally not EHF designed tools especially in the low and middle income countries (LMICs) viz. hand held devices, computer workstations, minimal invasive surgical diagnostic / therapeutic procedures, patient handling, slips, trip and falls due to wet floors or stairways, ramps or due to cables and cords, may also lead to various injuries by the exhausted staffs with reported work-related stress, WRMSDs, slip/trip/ falls and fractures. Different research groups and professional organization in the world reported reasonably high rates of WRMSDs especially low backache among all levels of healthcare workers that may impact on the fullest functioning in the chain of healthcare work due to the illnesses, injuries or other morbid conditions may affect errors at critical intersections that may jeopardize the safety of patients unintentionally leading to litigations against them.

Healthcare professionals working in the public health institutions encompass a good number of the workforce in India who are exposed to an array of EHF hazards. Research group in India attempted to assess occupational risk factors and risk associates among healthcare personnel working in public health facilities experiencing multiple hazards in different proportions. These observations indicated the imperative need to design and implement strategies to promote health of the healthcare providers [7].

Many healthcare professionals were reported to leave patient care tasks because of variable risks of physical hazards; significantly higher in residential care nurses than those in construction, retail or manufacturing workers. Most body parts affected were sprain in shoulder, low back, calf and hand muscles. Most common injuries in patient care were due to repeated handling, heavy manual lifting during transfer or reposition and working frequently in tremendously awkward positions that are more difficult in overweight and obese cases; more often when the patients move, resist, or physically or mentally not stable and elderly and flail cases; otherwise these difficulties multiply many times in hurried situations and crunch of manpower resources. This is also difficult during nursing, surgery, intensive care, respiratory difficulties, imaging studies, mortuary, and trauma care and emergency rooms; these may happen in all types of manual material handling also.

In the healthcare activities to move heavy objects, inclusive of healthcare tools/equipment/ instruments/supplies/linen/house-keeping materials/ cleaning solutions or sanitizers /furniture/food materials and even garbage WRMSDs are reported frequently. Many healthcare personnel by job responsibilities need to sit/stand for prolonged hours at a stretch e.g. nursing, surgery, imaging, dietary, laundry, laboratory, pharmacy, dentistry, administrative and maintenance – all these are uniformly stressful to experience WRMSDs and especially pain in different segments of the human vertebral column to keep same position for longer periods. Information technology personnel, users of hand-held electronic devices and equipment like gastro sciences procedures, laboratory technicians, surgeons and radiologists are at risk to be exposed to many types of static postures and repetitive movements of different parts of the body; the same is true for managerial, administrative and accounts areas.

To obviate these harms mechanical lifting tools, total/sit/stand lifts, adjustable height of bed/bath, self-propelled/manual wheelchair or other specialized mechanical equipments should have been readily / freely available in all places of patient care independent of weight-bearing status and medical/surgical condition of the patients depending on cost-effectiveness viz. slide sheets, walking belts [8].

Sensitization on self-care: most difficult task

Critical thinking, mindfulness, well-being at work, and socio-economic peace are intermingled for the optimum productive activities along with EHF compliance in infrastructure, logistics and tools healthcare set-ups. The healthcare personnel respond with best possible sincerity by their participatory contribution in organizational, national and international interest with mindfulness initiatives. In the last few decades computerization and mechanization has become an integrated part of fundamental metamorphosis of gadgets, tools and instruments in the healthcare set up. Further, in recent years spending long hours in front of computers has also become indispensable for administrators, academicians and researchers resulting in a number of many physical and mental health issues viz. eye problems, cervical and lumbar spinal issues, carpal tunnel syndrome, psyco-social stress, gastrointestinal problems, overweight and obesity among others [9].

EHF specialists studied human capacity in relation to workloads to explain role of human position and postures to locate / find proportionate / disproportionate static / mobile work schedules and forces; suggested to deduce ways and means to optimize / minimize by the adherence to the basic EHF principles to reduce harms. Stakeholders always need to consider probable downstream mortalities, morbidities and disabilities with a hidden agenda of loss of productivity and national economy. Modern researchers are unanimous that each workmen individual including those involved at all levels of healthcare will have to search EHF harms and hazards around their respective workplaces.

This thinking process as a grand observer of one's own joint and muscle functions and documentation can help the EHF specialist to collate by abstraction and thereby put the best possible solution based on ergonomic principles into practice tailor-made for those situations [10].

New world order - EHF has to care newer issues

Domiciliary carers at the doorsteps of the citizens are specially imparted by the family physicians as the unheard chapter of healthcare services from womb to tomb through the first-contact-care and last-contact-care health personnel. Home based innumerable and innovative ways of care in health and disease are usually (with brilliant exceptions) provided in non-ergonomic space and infrastructure especially in low- and middle-income countries (LMICs). All these add unaccountable stress to these basic health providers at the remote locations of rural/semi-urban/urban-fringes who wish to serve with their best possible clinical acumen at their office and on-call at the home environment of the care-seeker. These healthcare personnel accept mounting as well as ever increasing pressure from local administration and other stakeholders leading to frustration and fatigue 24x7 with infrastructure poor EHF compromised set up arranged by themselves usually. Thus these healthcare managements happen in favor of patients in relatively stress-free homely atmosphere smoothly even without ergonomically designed tools in LMICs. Further, in the domestic set-ups, the treating healthcare personnel have to innovatively guide modifications of the infrastructure and self-designed tools as per need and capacity of the patients / caregivers. This is definitely an uphill task for the best possible psycho-somatic safety of the patient with cost-effective logistics with options and choices for people of all economic standards in absence of any national EHF policy for healthcare.

The hidden global pandemic of physician burnout is a contentious issue with direct negative impact on the long-term health of the healthcare providers. This has an indirect effect on the safety and quality in the spectrum of patient care rooted in compromised and exhausted healthcare. There is also an urgent need to understand human interaction with this more and more multifaceted multitasking of workstation cognitive ergonomics with physical ergonomics to understand human factors in the total range of healthcare workplaces. Since the second half of the past century major changes of outsourcing of work or individual from the main workplace with rapid advancements of science and technology specially in IT jobs, accounting, managerial etc. primarily for cost containment. Later on, with the advent of telemedicine/telemedicine in this new millennium remote work set-ups is cropping up, though yet to cross infancy in LMICSs. Further, pedagogy as capacity building in healthcare education has been growing in leaps and bounds as a phenomenon with much debate embedded within. The shift of workplaces dedicated for the individual healthcare / continuing medical education / conference / webinar to the remote office / domestic / personal setup was augmented / heralded by the COVID-19 pandemic lockdown periods. This paradigm shift has been surprisingly stressful and sentiment of helplessness even for many efficient healthcare personnel as well as educated citizens truly enough. We have to accept the bitter pill that even in well-to-do homes, there remains paucity of dedicated office cum public spaces unless these are provided by the employers and/or stakeholders for their own vested interest. Many individuals had to organize make-shift transport arrangements and/or office spaces that may or may not have EHF compliance for safe working for longer hours of day/night at a stretch within four walls of their comfortable home environment [11. 12,13].

Ergonomics and human factors in India

The Indian society of ergonomics

The Indian Society of Ergonomics, affiliated to the International Ergonomics Association (IEA), Asian Council of Ergonomics and Design (ACED), and BRICS plus Ergonomics Network, is the only professional body representing ergonomics / human factors in India. Established in 1983, Indian Society of Ergonomics is multi-disciplinary involving personnel from physiology, psychology, home science, industrial and product design, occupational health, industrial safety, and engineering [14].

Training facility

The occupational safety and health issues are subject to the Ministry of Labour and Employment under the Union Government of India. The Industrial Safety and Health branch discharges the overall functions relating to framing policies and formulating guidelines for nationwide implementation of laws in relation to safety at workplaces including healthcare establishments. The Directorate General of the Factory Advice Service and the Labour Institutes (DGFASLI) was established in 1945 in India to advise Union and State Governments with Headquarters and Central Labour Institute at Mumbai, Regional Labour Institutes at Chennai, Kanpur, Kolkata, and Faridabad. Central Labour Institute, Industrial Medicine division advocates prevention and containment of harms at workplaces with surveillance and documentation. Industrial Physiology division emphasizes research, development and consultancy services in Ergonomics to improve working conditions with designs of workplace environments viz. psychosocial stress, industrial ergonomics by assessments and evaluation of the natures of work organization by interprofessional research studies for optimization of safety of human health and welfare with cooperation; also offer Fellowship and Certificate courses. The Ministry of Labour & Employment, Government of India, promulgated National Policy on Safety, Health and Environment at Workplace in 2009 and uploaded in the website of the Ministry of Labour and Employment and DGFASLI to promote paradigm of safety and human factors and well being of workmen in the national economic activities; viz. a) Safe and healthy working environment is a fundamental human right; b) Enhance well-being of workmen as well as of society by eliminating work related injuries, diseases, etc. c) Achieve and focus the objectives of reduction in incidence of work related injuries and diseases [15].Ergonomics introduced to Indian businesses

Ergonomics is a developing discipline in India and in recent times, the basic principles are being sincerely incorporated and implemented into in commerce and businesses. The inroads of safety practices in small and medium enterprises (SMEs) has been noted to minimize minor accidents and ergonomics snags, improve technology and awareness from global influence to improve functioning of the living tissue/organ/systems with full ergonomic solutions in tailor-made ways. Indian entrepreneurs are putting incredible efforts to produce ergonomically compatible furniture for domestic as well as office spaces for working in cozy longer office hours. There is ongoing research on different issues even when the workmen need frequent change of operating workstations suiting multilingual country's multi-ethnic / indigenous cultures in mind[10]

Evolution of conceptual frame of ergonomics in healthcare

From time immemorial since human civilization in prehistoric times our predecessors had to face varied challenges to endure with all the antagonistic natural harmful and hazardous risk factors against their survival. Before the path-breaking invention of cultivation on land and water was learnt, primitive folks survived with the consumption of what they could have collected from the natural resources of the earth, whether vegetations or subhuman animals from hilltop to seabed. Later on with their inductive and deductive hypothesis and using indigenous instruments they initiated a long journey of cultivation to exploit the resources ``Mother Earth” including domestication of wild subhuman population and animal husbandry for basic demand of their lives. An urge of continuous updation made human civilization self-sufficient with the creation of unexpected quality and quantity of foodstuffs and basic requirements for the billions of global citizens till date. With the exponential growth of basic logics, the path-breaking uncountable inventions kicked off through industrial revolution all the growth of civilization was formally and unanimously termed as progress. The downstream effects of the explosion of science and technologies with inestimable developments and discoveries have converted us slaves of instrumentation in the urbane society. From our age-old mission and vision of confronting the fierce nature, our thought processes have been slowly shifted to comfort zones. Our mind-sets have been shifted to the turfs of supremacy over another and exploit weaker sections to keep us with lesser mechanical movements and sedentary lifestyles. In the healthcare arena for example, even those usual workloads which were labor-intensive a few decades back got a total face-lift a long way down the lane in terms of addition and or deletion of human labor. Yet, it is a bitter pill that the developments of technology have not given due respect to the science and art of EHF designed infrastructure to help the manpower resources to discharge their duties and responsibilities with ease. In spite of all these adversaries, the healthcare communities of the LMICs are obligated by their commitments to interact with those in need at their doorstep 'whatever they can help them' whether they are apparently healthy without overt disease irrespective of caste, creed or religion.

The safety of patients with the application of the concept of EHF is a recent offshoot from mainstream machinery production lines when healthcare has been visualized as an industry metamorphosed from a 'noble profession' of individual care of caregiver to anyone in health and disease on one-to-one basis. New ways to solve age-old problems or researches was initiated from observing all the healthcare personnel at each workstation with checklist for all critical factors is the basic step in research on ergonomics and human safety as healthcare is conglomerate to uncountable factors from pre-hospital/domiciliary care to end-of-life care/ medicolegal autopsy. This will have to be followed by sincerely motivating all healthcare personnel with suggestion to practice right posture at work stations using right height of working/writing desk with right screen position in the right kind of temperature with right kind / amount of light among other cognitive/psychosocial factors depending on age and gender are part of researches. We need to cultivate a holistic EHF mindset at every place with 'safety first' principles for the patients. This needs to be supplemented with a series of continuing assessments at each workstation with regular activities round the year for optimum healthcare service and safety at healthcare establishments of all levels as systems approach [10].

The application of EHF has to be discussed within basic frameworks of four demands of healthcare work environments in line conventionally with other workplaces viz. a) physical/physiological e.g. lifting, moving; b) skill/efficiency e.g. documentation; c) risk/harm e.g. shifting patient with suspected injury of head/neck/spine/limbs; d) time/compulsion e.g. trying to finish all the work on time schedule. In the healthcare psychosocial environment, the paramount importance is to be laid on team approach, pace of life, lifestyle issues in relation to working hours e.g. space, leisure, and expectation of quality of life along with physical environment a) physical e.g. heat, noise; b) chemical e.g. suspended particulate materials in ambient air; c) biological e.g. nosocomial infections. In the era of the explosion of science and technology of ergonomics and human factors, and their applications even at the grass-root levels viz. a) designing product dimensions using anthropometrics and biomechanics data; b) hardware designing and displays to meet user expectations; c) software designing from diagnosis to interventions; d) safety issues - ambient conditions and tools/furniture; body dimensions and capabilities in terms of anatomy/physiology; motivation, fatigue, training, retrieval; job demands; job design; organization type/climate, scalar/hierarchical management. The objectives of EHF are a) Enhance the efficiency and effectiveness minimizing errors; b) highlight human values over price by boosting safety/ comfort/ satisfaction / quality of life for all people (able and differently-abled people) by decreasing fatigue/ stress on individual[16].

The health problem due to working conditions was noted even in writings of ancient Egyptian, Greek and Roman periods. In 400 BC, Greek civilization postulated the design of hand tools, sites and workplaces; Hippocrates framed the design of the workplace and tool of surgeons. The incessant search of harmful elements and ideas of solutions at workplaces on EHF since the beginning of the industrial revolution are valid even for today for all levels of healthcare workplaces.

These are from earliest documentations in the seventeenth century by Bernardino Ramazzini of the novel interpretation of working conditions and pathology in his book 'De morbis artificum diatriba' viz. WRMSDs usually associated with repetitive motions and/or awkward postures; earliest idea of innovative promotion of introduction of standing desk for professional writers to relieve their stress of sitting for longer duration in eighteenth century; qualitative and quantitative assessment of apiece motion and effect on overall workflows was done on specific activities in nineteenth century, yet safety / welfare of workmen was not at centre-stage of these research thoughts; placing of operational tools viz. dial, indicators, gears etc. within reach in aircraft, tank and ammunition used during two successive world wars; Christensen's pioneering concept of 'good fit' between humans and tools in the twentieth century. All these innovative safety models included work interface, applied psychology of human cognition, burnout and human errors were later on progressively more empathetically applied in healthcare to redesign infrastructure, tools and procedures for safer healthcare paradigm. Initial sensitization on the EHF benefits followed by continuing training / retraining have generated high levels of interest among healthcare professionals to critically prioritize and apply safety principles to patient care even at extra-hospital set ups with user-friendly cost-effective equipment. Japanese researchers fruitfully started to amalgamate the concept of human engineering with American psychology to 'economically' utilize human labor. Researches began in EHF in twentieth century a) muscle force vs. manual tasks, b) lifting vs. compressive low back disk force, c) heavy labor vs. cardiovascular response, d) perceived maximum load to carry, push or pull, e) cognitive domains to understand human factor/behavior/attributes viz. decision making, organization design, human perception on design, f) physical aspects of the workplace viz. human abilities vs. force requisite to lift, vibration and reaches called industrial ergonomics.

EHF research have ingeniously merged the interprofessional research and development (R&D) collaboration of basic science experts including physiologists, engineers, occupational interventionists and hygienists, basic and applied psychologists, safety personnel, IT people, architects, nurses, paramedical and para-clinical experts, sociologist, philanthropist, legal experts and insurance specialists [17,18,19,20].

Thus, there are unlimited opportunities to explore, extrapolate, innovate and implement concepts of EHF in healthcare settings to find good understanding between human factors with machine and cognitive and physical environment viz. Research and development, Health Economics, Hospital Ergonomics, Burnout issues of healthcare providers, Remote location healthcare, Clinical safety programme, Laboratory Ergonomics.

Yet there is a dire need to include ergonomics in healthcare teaching-learning in pedagogy and andragogy of the undergraduate and postgraduate levels, Sustainable Ergonomics, and many others. Our research groups members have tried their level best to incorporate ideas in this book so that healthcare personnel can innovatively implement EHF in their current / upcoming / future healthcare practices. The research groups in India working in the field of Ergonomics and human safety are attempting to change the EHF issue to better match capabilities, limitations and needs of people based on anthropometric data as in the informal sectors in India an estimated 84.2 % (2005-2010) get their earning; others estimated that workmen in the informal sector constitute more than 93 percent of the total workforce (c.f. National Commission for

Enterprises in the informal Sector, 2009). It has been hypothesized that healthcare services are informally spread in predominantly rural populace in India with grossly EHF compromised set ups [21].

Avenues of implementation of ergonomics and human factors for patient safety

The central theme to patient safety is entrusted on the integrity of the healthcare professionals, who as the bandmaster of the healthcare orchestra organizes delivery of care on ground in the workplaces. The goal to ensure patient safety in systems approaches for the holistic benefits of all in the healthcare arena is embedded in both improving human accomplishment and harm reduction. To augment efficiencies and safety of healthcare with highest quality of positive health, the package should focus to predict performance, safety and satisfaction from team perspectives of clinician, nurse, pharmacist and others in the healthcare organization. Further, we need to walk on both feet with vital insights on the psychosocial as well as cognitive factors along physical ergonomic improvements at healthcare establishments. Advanced EHF research issues are a) modeling systems vs. economic aspects (c.f. outpatient surgery), b) IT healthcare information technology, c) engineering work system model vs. patient safety, d) cognitive aspects vs. computer interaction, e) poor office layouts and workflow design vs. burnout, f) universal health coverage vs. global health, g) ergonomics, human factors and patient safety, h) health information access for all, i) home-care nurse vs. home-dwelling self-monitored and self-managed patient, j) prevent/intercept/correct errors by technology boom vs. MSDs bang among doctors/nurses, k) resilience vs. traditional error reduction for patient safety, l) evidenced based medicine vs. clinical acumen to improve safety (c.f. near miss), m) new technology vs. design and ergonomics perspective [22].

Body and mind spun together

With the scalar principle of 'safety first mindset' for the patient at the healthcare grass-root level we need ergonomically redesigned clinical practice guidelines, standard office procedures amid EHF compliance in infrastructure and logistics. All forms of humanizing in relation to dissimilar work-stations and orientation of work materials are the call of the day to suit the patient's safety. Personal protective measures, Control of newer hazards, administrative and legislative supports from stakeholders with a human face altogether ensure highest safety from the healthiest healthcare workforce particularly of LMICs; working in isolation in remote situations by primary care practitioner in EHF compromised situations add stress with increasing fatigue and feeling of being disconnected [23].

Research and education in ergonomics

Research on ergonomics on patient safety should be targeted on kinetic and kinematic changes in the weight-bearing joints in relation to gait phases, spatial and temporal parameters in comparison to healthy individuals. The EHF researches start with various steps in assessing risks and end with various mitigation and remedial measures to interventions at different levels of natural history of diseases in occupational morbidities in tailor-made ways. Assessments in ergonomics are done by different ways and means viz. the Nordic musculoskeletal questionnaire to screen MSDs in the ergonomic context and for occupational healthcare service. It focuses on nine areas of the body. It has two components: the generalized questionnaire focuses on which area of the body while the special questionnaire concentrates on the anatomical area in which symptoms are most common [24]. Further, the Eye strain survey questionnaire includes questions about demographic information, personal eye care, PACS versus film use, work habits, and workstation and interpreting environment design [25].

Importance of ergonomics in the new millennium

Patient safety is central to healthcare and upcoming decades have predicted higher demand in the healthcare sector as the fastest socio-economic sector. Healthcare providers have to encounter distinctive health hazards during discharge of their varied occupational activities that stems from working under an odd ergonomic paradigm, if unchanged. Historically, all developments in technology were driven by economic forces; yet. EHF principle walked in a different path ensuring safety with responsible stewardship of community resources based on moral values and standards. Scientists working in the field of sustainable ergonomics provide long term vision with better returns encouraging passionate inculcation for EHF philosophy. All these demands ample EHF attention to halt this saga leading to burnout and journey towards job contentment and safe healthcare.

Stress as additional factors: on and off the work

Situational analysis shows that till the other day, all healthcare requirements of the citizens were managed by the health care providers of different shades who all feel comfortable as their friend, philosopher and guide available at their doorsteps. We all have experienced in our younger times how they cared for us from the bottom of their heart at odd hours not looking back at their personal comfort. EHF issues at home add fuel to fire as the knowledge and practice of EHF is yet to reach the arena of home environment on a large scale in the new world order of 'Work from home'. So when the healthcare personnel reach home, they may not get ergonomically designed furniture to relax and return to work the next morning with a fresh body and mind. Everyone in this complex and complicated world is stressed in micro and macro environments and healthcare personnel are no exception but strangely they absorb stress better as part and parcel of their job responsibilities. Now the question is when the doctor himself is stressed and burned out on how he can treat the patient who carries the anxiety at healthcare settings along with ailments. There are many reasons that are causing higher stress in healthcare workers, even though; India has reached the doctor-patient ratio 1:1000 as recommended by the World Health Organization. The infrastructure poor EHF compromised work environment is adding fuel to fire in absence of integration of tasks of patient care to fit the healthcare providers to minimizing the harm.

The health care facilities have to be remodeled from ergonomic stressors with reasonable costs, optimum turnover, and healthy working milieu. With the mindset of safety, interventions have to focus on kinetics and kinematics of awe of our human body. This introductory chapter of the book of ergonomics targets to sensitize all levels of healthcare practitioners to help them internalize the conceptual and contextual framework of the EHF and safety principles as applicable to the variety of healthcare settings. Incremental practices of basic tenets of EHF increases patient safety in the healthcare arena and decreases psychosomatic injuries of all forms in all parts of the living issue-organ-system along with increment of quality and quantity of productivity [26].

Conclusion

EHF is still an orphan chapter in the era of path-breaking inventions, life-saving discoveries, and protocol-based intervention plans in the healthcare parlance. We are taking billions of steps toward transparent and bioethical systems approaches in the patient care moreover than with minimal attention to EHF. The reason is crystal clear – courses and curriculum for the capacity building / rigorous training / competency / skill regarding neither EHF / patient safety is out of vision by the educationists historically. This research group feels that EHF and patient safety should be the 'Must Know' area of all levels of healthcare training in general, and of competency based medical education programmes at undergraduate and postgraduate levels in particular for learning the truth of EHF related outcomes.

Healthcare paradigm is changing everyday and during treatment of the person we have to take into account EHF factors rather than just managing symptoms and signs of any health issues presented by the health-seeker. We need a holistic approach with health system strengthening with human resource development, capacity building, health regulation and health information system to weed away ergonomics related morbidities. Researches should be encouraged on innovation of models of work system design and implemented with feedback for patient safety and concept of ergonomics. ILO Director-General Guy Ryder explained in his own language "Everyone has the right to work in a safe and healthy environment, regardless of the industry they are in or the type of work that they do."[21]

Key points

1. Ergonomics and human factors is a evolving discipline in healthcare
2. With improved ergonomic approach, we'll make healthcare comfortable for providers
3. Practical approach needed to improving safety in healthcare environments
4. Translational research needed in this neglected healthcare agenda
5. Intensive discourse among peers indicated to find ways to mitigate the harms

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Chapter 6

Ergonomics in the Intensive Care Unit

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Learning points

After reading this chapter, the reader will be able to

- Explain the importance of adequate ergonomics in intensive care units.
- Recognize the beneficial effects of the proper ergonomics for the ICU staff.
- Determine the ICU burdens and the recommendations to avoid Work-related Musculoskeletal Disorders.
- Identify the Burnout Syndrome risk among the ICU Staff.

ABSTRACT

The Intensive Care Unit and Critical Care are part of the most challenging current medical practice levels. It is in this environment where the physician (and all the members of the critical care group) helps the patient into the course of the illness, whether to have a proper death or to surpass the disease and get an adequate improvement to continue with optimal health status (when it is possible). These units are one of the most important facilities that a hospital must consider, and the medical attention will be focused on very few patients compared to other departments. However, it is here where life or death is "decided". All the critical care members work 24 hours and seven days a week, with long shifts to improve the patient's management, sometimes the personnel is not enough, or maybe the workplace and workload might not be the correct one. The present chapter discusses an overall presentation on the factors that might affect the intensive care units' proper ergonomics. Simultaneously, considering that when these are correct, the beneficial effect will be to the medical staff and the patients due to a better physical, emotional, and mental health of the personnel that will lead to better attention and treatments.

Introduction

The Intensive Care Unit（ICU） is one of the most complex facilities in a hospital; it is here where patients experience multiple life-threatening situations due to their illness. Here, the mortality rates are significantly higher when comparing other hospital departments. There are numerous "types" of ICUs in a hospital（i.e., pediatric, neonatal, obstetric, internal medicine or medical, coronary, burn patients, and surgical）. But there is something clear about these, regardless of their type of patients （or treatment objectives）; these facilities are the most challenging due to their patients' critical health status. Even if the total census of an ICU is small compared to other in-hospital departments, the daily treatment challenge, and the patients' characteristics are significantly more difficult.

Overview

Daily, the intensive care physicians face multiple choices about their patient's diagnosis, treatment, prognosis, and even how to approach, and, as we previously mentioned in another chapter in this book（*See the Ergonomics in Neurosurgery Chapter*: *An Introduction*）, there is a "culture" in the medical practice of ignoring the strain, pain, discomfort, and the physicians' well-being, to give the patients the best care we can to achieve a better outcome when possible. Related to this, the critical care and ICU staff （physician, nurses, therapist, among other services and specialists） in their practice face a lot of burdens（physical, emotional, or professional）, for this reason, is a high risk of suffering from Work-Related Musculoskeletal Disorders（WMSDs）.

WMSDs and musculoskeletal pain are pretty frequent for caregivers, but in the ICU might present a higher prevalence. The inadequate ergonomics, physician strain, stress, fatigue, workload, burdens, and critical patients （with non-improvement） or the burnout among the medical staff might lead to medical errors that will end as one of the leading causes of deaths. Also, it is essential to remember that WMSDs will affect the healthcare worker's career length and quality of life.

Back is the most frequently injured, shoulders, arms, knees, neck, and head pain are presented; patient care, extended hours shifts, and individual burdens predisposed to these injuries. Nevertheless, in the medical practice, the usage of Electronic Medical Records （EMR） and checklists for procedures and multiple tasks（even if despite its benefit, some professionals do not welcome the use of lists） are related to reducing human errors, workload, and burden. Still, WMSDs appear in acute conditions; sometimes, these might take several times before being evident due to the cumulative microtraumas and the lack of adaptation to physical stress. The different scenarios that might contribute to these issues are discussed ahead.

ICU as a unique workplace

The work environment is an essential factor that might affect the employees' work satisfaction and motivation; in the ICU settings, there is some risk related to occupational hazards. The work environment must be carefully considered because it will affect the motivation and ability of ICU workers to perform tasks. There is evidence that poor working conditions can affect the outcomes of healthcare professionals and patients. ICU hazards include ICU workers' motivation and ability, equipment, space), work conditions (daily workload, shifts, standing position fo, patients' critical status, patients' outcomes incomes), psychosocial factors (perceived as the professional satisfaction, stress management, frequent patients deaths, workplace violence, etc.), ergonomic factors (as the patients' positioning, repeated movements and facilities ergonomics), and biological and chemical factors (gases, chemical substances, secretions, fluids, etc.). Because of these hazards, ICU staff (especially nurses) will be transferred to other departments of the hospital after working in the hospital for a period. Like many other wards in the hospital, there is a shortage of personnel in the ICU. primarily have shown that insufficient staff hospital departments on the prognosis of patients. Not only will the number of personnel prevent patients from unexpectedly negative conditions, but the working environment will also improve the patients' prognosis.

ICU and risk of injuries

The ICU is characterized by high-quality care and attention to patients in a critical state; ICU hospitalized patients are different from other healthcare settings, especially for the care they require. Here, the patients are treated by a multidisciplinary team; this means that the Intensivist must retain and communicate a lot of information from multiple sources to make a team-based decision. Many of the harmful consequences of stress include high sick leave rates, absenteeism, high turnover rates, and deterioration in productivity and social climate. These are triggered by WMSDs, which are the most common health problem among all work-related disabilities and injuries. There are two essential factors in developing occupational WMSDs, namely "repetitive fatigue" and "cumulative trauma". In the long term, acute overwork may cause or build muscle, bone, or tendon damage that might occur in any part of the body. It is important to emphasize that WMSDs are mainly related to organizational factors, such as the type of hospital, the kind of shift work, and the frequency of work schedule changes, rather than personal factors. ICU's with high census and sicker patients with physicians attending to codes frequently present higher mortality, maybe because of the strain impacts in care quality.

Burnout syndrome among ICU staff

Burn-out is a job-specific syndrome is a work-specific syndrome and has a high incidence among ICU personnel, manifests as emotional exhaustion, depersonalization, and lower interaction with people. This is more likely to happen when goals and expectations are too different from reality, leading to an imbalance between investment and resources obtained. BOS has obvious characteristics of interpersonal relationships, especially affecting those who engage in demanding jobs and establish close relationships with them; considering the characteristics of work in the ICU. This is a demanding task involving life and death decisions, so ICU practitioners are expected to face a high risk of job burnout; this high-risk population presents a prevalence of up to 50% of BOS suffering. Psychological hazards in the intensive care unit can lead to a psychological burden, mood changes, sadness, negative perceptions of overall life, irritability, loss of confidence, and negative self-image. The consequences of high pressure in the intensive care unit may lead to increased absenteeism, reduced productivity, more accidents and personal injuries, higher job turnover, and increased costs. The existence of a high BOS rate in the ICU is only related to behavioral and psychological characteristics, that is, higher trait anxiety, difficulty in taking precise actions, and fear of having made medical errors in the past. Factors such as heavy workload, frequent night shifts, workplace environment, high patient mortality, ethical issues related to end-of-life care, and unrealistic expectations of patients' families may be part of the cause of this situation.

Medical monitors

The ICU is equipped with various technologies to provide support for emergency patients with complex medical needs. Many devices surround the ICU patients as the vital signs monitors, supporting devices, therapeutic devices, fluid or gas administration devices among others; many devices can measure up to even 20 traces (some others merely provide a basic measurement). Usually, the physiologic signals are measured in continuous or periodic intervals, and only when an abnormality is detected will it display the alarm, but when multiple alarms are sounding, it could be as if they were "fighting" for the staff's attention. However, the human brain only assimilates a few of them; one of the main issues in the ICU is the rate of monitors false alarm; because this is quite frequent, it can lead to a desensitization of the proper alarms. When multiple alarms are activated, certain sounds mask other alarms because of their intensity and acoustic. A correct monitor data interpretation is mandatory because it allows the physician to answer more rapidly according to the patients' condition and prioritize needing faster attention.

ICU design

The design of the ICU infrastructure should prevent the interference caused by high noise in the ICU; higher noise causes increased stress for the ICU staff. The ICU environment requires proper physical layout and workstation design. On the other hand, insufficient space in the patient room or bed can make it difficult to interact with the patient and the provided equipment effectively. According to some studies, when ICU patients' rooms were single rooms, it had positive outcomes for family and patients' privacy and the staff regarding the patient-physician relationship and dialogues privacy, reduced job stress, and enhanced noise, and a less hectic work environment.

Time usage

ICU workers are more vulnerable to injuries caused by mechanical hazards because they provide care to patients in unstable conditions; in this case, the nurses have the highest risk of occupational hazards due to a bad ergonomics process. It is important to mention that ICU workers face chemical hazards, such as exposure to antiseptics and disinfectants or their gases' inhalation. Exposure may occur in various ways, usually through the penetration of the lungs after inhalation and the absorption of the skin or mucous membranes through the eyes or nose. It is recommended to suggest some workplace interventions in the ICU setting to control and manage risks, and most of these interventions focus on the behavior change process. They do not use the equipment for different reasons, such as the difficulty of using the equipment or the time-consuming (disinfecting all the parts each time).

Workload

The workload perception depends on the individual and his/her experience; for example, recently graduated or new members might feel a higher workload compared to those who have more experience working in the ICU. Even though it is known that ICU work characteristics require extended work hours schedules, which can lead to physical and mental fatigue. Also, long shifts (12 hours and above) will increase errors and reduce team vigilance. The impact of excessive workload in the ICU environment can lead to higher stress, job dissatisfaction, and personal injury (especially considering the low salaries compared to working conditions). Due to excessive workload and fatigue, there is a direct correlation between shift time and burnout. Literature studies have shown that there is a correlation between increased workload and higher medical errors and hospital-acquired infections. Strenuous patient care activities can lead to long-term fatigue, reduced physical fitness, and weakened muscles. The weak parts are particularly vulnerable to mechanical loads and injuries, and the most common symptoms are muscle and joint pain, especially in the spine.

Preventing injuries

Reduced job stress, more privacy within the patients' room with a proper family space accommodation, efficient and good teamwork, and the proper usage of the technology; are factors related to achieving better work satisfaction. In some cases, the ICU workers' medical history should be recorded to keep in mind their comorbidities and consider them concerning the multiple ICU hazards. It is not a secret that exercise and healthy life habits will affect the personal and professional life of the health care provider positively, so it will be useful to remind then now and then the importance of these, concluding, as a community, for the benefit of our trainees, ourselves, and our patients, we must face the challenge of improving the health (physical, emotional, and mental) of the medical staff while reducing the risk of BOS and WMSDs. Improving working conditions is a top priority; health is essential to the training of physicians. Currently, doctors (regardless of their work as ICU, general, or some other specialties doctors), are experiencing a high incidence of depression and burnout. It is important to develop interventions to optimize health and prevent depression and burnout. It has been shown in some recent studies that personality traits and behavioral characteristics are associated with the BOS incidence rather than the sociodemographic and occupational issues; for this reason, improving the work environment might not be sufficient for BOS prevention.

Conclusions

Working in the ICU is a medical challenge because of the knowledge required and the different situations that could be faced every day with the patients' and their health conditions. For this reason, suffering from WMSDs and burnout syndrome while working on the ICU might be pretty standard. It is important to bear in mind that excessive workload decreases the ICU staff's performance. Even more, when the organization does not fulfill high-quality criteria, the physical environment will not be the most comfortable. Thus, it will influence the professionals and their accuracy and efficiency in a bad way in daily practices. When this type of situation occurs, it can lead to higher stress rates, fatigue or strain (emotional, physical, and mental), burnout syndrome, and WMSDs that will end up in medical errors that might affect the patient's approach, treatment, and outcomes.

Key points

- The ICU physician burden ranges from administrative to healthcare delivery. It is important to assess the proper environment to avoid work-related injuries and WMSDs.
- It is important to organize the time spent during the ICU and personal activities; this will reduce the BOS risk and improve mental health.
- A workplace environment correctly organized reduces the health care staff's fatigue and allows them to recognize the different ICU alarms and the different hazards properly.
- Single rooms for the patients allow higher privacy and more interaction with the patient family. More time with a patient and less time with paperwork sometimes mean more job satisfaction.
- Reducing BOS risk will reduce suicide, depression, absenteeism, retirement, among some other hazards risk that will affect not only the health care staff but the patient and his/her outcomes as well.

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Chapter 7 Ergonomics, Musculoskeletal Disorders and Patient Handling

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ABSTRACT

Physical ergonomics focuses on the relationship that the human body has with the surrounding environment, taking into account the corporal manifestations derived from musculoskeletal tension, repetition of movements, posture, handling of instruments and the planning of the workplace, evaluating these according to the appearance of musculoskeletal disorders, fatigue, discomfort and physical effort. Musculoskeletal disorders are a growing concern globally due to their great impact on the general health of the population, because of the prolongation of the human life expectancy the appearance of these diseases is more perceived especially in the healthcare system as a result of prolonged waiting times for patients and lower quality care by health personnel. In addition the economic impact that does not affect exclusively the employee, but also affects companies as a result of the high costs caused by absenteeism, decreased productivity and increased costs of healthcare, disability and workers' compensation. Efforts to find adequate solutions have been based on the study and application of ergonomic intervention through risk management strategies that have demonstrated reduction of fatigue, stress and injuries. Nonetheless, these are not sufficient to address the increasing appearance of musculoskeletal disorders in surgeons and similarly decrease the poor implementation of formalized ergonomics programs, which have an undesirable impact on the level of education regarding this subject as a result of their deficient application in the clinical practice. On the basis of the above, the objective of this chapter is to present aspects related to ergonomics, musculoskeletal disorders and patient handling.

Introduction

The word "ergonomics" derives from the Greek ergon (work) and nomia (disposition), according to the International Ergonomics Association it is defined as the profession that comprehensively addresses the physical, intellectual and organizational dimensions of human activity by applying the theory, data, design principles and methods, in order to evaluate parameters of safety, comfort, productivity, utility and aesthetics through the design of tasks, products and environments, thus optimizing human well-being and overall system performance, under the concept of designing the work conditions with the aim of adapting them to the worker, instead of forcing the worker to adapt to the settings (1-4). Physical ergonomics focuses on the relationship that the human body has with the surrounding environment, taking into account the corporal manifestations derived from musculoskeletal tension, repetition of movements, posture, handling of instruments and the planning of the workplace, evaluating these according to the appearance of musculoskeletal disorders (MSD), fatigue, discomfort and physical effort (1, 4, 5). Psychological ergonomics studies the functioning of cognitive processes, understanding of sensory and motor functions and perceptual memory, assessed through emotional loads, stress, frustration and well-being. Organizational ergonomics focuses on environmental influences, workflow processes, and even the guidelines employed in the workplace (4, 5).

The MSDs, previously called cumulative trauma disorders or repetitive stress injuries, are conditions or organic dysfunctions that affect the musculoskeletal system of the human body, more specifically, muscles, bones, nerves, tendons, ligaments, cartilage, joints and spinal discs, where they can develop afflictions such as sprains, twists, tears, discomfort, pain, carpal tunnel syndrome, hernias and connective tissue injuries, which are causally related to the conditions and performance at work or exacerbated by them. (2, 6-8). Several factors have been associated with MSDs such as repetitive movements, excessive force use, awkward or sustained postures, prolonged sitting and standing (7, 9). The World Health Organization (WHO) describes the term work-related MSD as a broad spectrum of inflammatory and degenerative diseases that result in pain, discomfort and disability due to activities carried out in the common workplace environment (10). The mentioned ailments can range from mild and transitory to irreversible and disabling that are aggravated or intensified by work. It is established that the different stages these injuries go across are comprised of: the first stage, which corresponds to those symptoms that occur during work and resolve themselves, the second stage, for its part, corresponds to those symptoms that do not resolve overnight after a day's work but they do so over time and finally, the third stage corresponds to symptoms that persist at rest for months or years, and interfere with sleep (2).

Impact and implications

MSDs are a growing concern globally due to their great impact on the general health of the population, because of the prolongation of the human life expectancy the appearance of these diseases is more perceived especially in the healthcare system as a result of prolonged waiting times for patients and lower quality care by health personnel (11). In addition the economic impact that does not affect exclusively the employee, but also affects companies as a result of the high costs caused by absenteeism, decreased productivity and increased costs of healthcare, disability and workers' compensation (12). According to reports between 2013 and 2014, 8.3 million work days were lost in the UK due to symptoms caused by MSDs (13).

In turn, in the European Union (EU), more than 40 million workers suffer from some condition belonging to this group of diseases, which corresponds to one out of every seven affected workers (14). As a result, this raises the socioeconomic problem from the high prevalence of MSDs in the world population, the economic costs derived from these injuries can be classified into direct, indirect and intangible. Direct costs are those derived from medical expenses that are used to cure and prevent diseases; Indirect costs are those produced by the loss of productivity, training and the costs of hiring new employees, and the intangible costs correspond to the psychosocial burden such as work, family and economic pressure, therefore affecting the quality of life of the worker. In the United States, the economic cost of MSDs is estimated between 45,000 to 54,000 million dollars, which includes repatriation expenses, lost productivity and wages, the direct costs of workers' compensation are estimated at 20,000 million dollars, and the indirect costs can ascend five times higher than the direct ones. For that reason, it is necessary to reduce the appearance of cases related to MSD at a global level (14-16).

Work-related MSDs are considered a phenomenon with a great impact on the workload, as a consequence of the low productivity of the personnel, as well as in the increase of absences of the workers, shortening the longevity of their working life and even forcing them to an early retirement regardless of their age, experience or gender (17,18). MSDs are common within the field of health care, especially in those surgical specialties and subspecialties that have static and uncomfortable work postures, repetitive work patterns, and long working hours (8, 19, 20). Although it is true that thanks to the development of minimally invasive surgery, improvements have been made in the care of patients such as less pain and discomfort, shorter hospital stay, faster recovery time, lower risk of infection, decrease in intraoperative and postoperative complications, less blood loss, reduction of transfusions and better aesthetic results, inevitably this has increased the appearance of MSD in surgeons thanks to the corporeal stress represented by the lack of physical, visual or direct access to the anatomy of the patient, the bad design of the tools and the decrease in the degrees of freedom when operating that create uncomfortable working postures and a limited two-dimensional vision of the surgical field causing an excess of somatic and cognitive workload, affecting the quality of life of surgeons and indirectly the care provided to patients (1, 3, 5, 18, 21, 22).

Various researchers have established that health sector workers do not report the appearance of symptoms corresponding to MSDs in a prompt manner or seek medical attention, preferring to take analgesics for relief along with minimal rest outside the operating room or work station, which has a negative impact on their professional performance and social and personal life. There is no correct estimated prevalence of this problem due to the lack of notification and collection of cases, so the data is undervalued. Furthermore, thanks to the complexity of the development of MSDs, the attribution of causation is a challenge, and the data on compensation does not collect the information with great precision (8, 9, 18, 20, 23).

Efforts to find adequate solutions have been based on the study and application of ergonomic intervention through risk management strategies that have demonstrated reduction of fatigue, stress and injuries. Nonetheless, these are not sufficient to address the increasing appearance of MSDs in surgeons and similarly decrease the poor implementation of formalized ergonomics programs, which have an undesirable impact on the level of education regarding this subject as a result of their deficient application in the clinical practice. These recommendations have little to no significance in the culture perpetuated by surgeons, which encourages self-denial in order to prioritize patient care (2, 18, 24).

Likewise, it should be noted that this problem is not limited to professionals in the surgical or health care area with extensive work experience, ergonomic challenges and the appearance of injuries can also be observed in residents and young surgeons when they learn surgical techniques due to their location in the surgical field as they do not have the power or control to decide about the position and placement of equipment in relation to their actual needs, along with this, the time pressure in the operating room and lack of knowledge and awareness on the subject can also affect them.

Therefore, a complete training in ergonomics is suggested during the academic studies of medical professionals from the beginning to reduce the appearance of MSD, increase worker satisfaction and thus the longevity of the practical career (8, 10, 25-28). The participation of teachers is essential through the provision of information on ergonomics and the use of simple checklists (24).

Risk factors

Risk factors linked to MSDs in the context of occupational activities are classified in three groups: physical factors, organizational and psychosocial factors, and factors dependent on the individual, interaction between these three groups accelerates the appearance of the clinical symptoms (9).

Physical risk factors

The development of MSDs is causally linked to the physical load of occupational activities. In its majority the injuries that affect tendons, joints, bones and ligaments are caused by mechanical overload on these anatomical structures, which causes high tension forces and twists that act within the body, and their effect is dependent on the magnitude of the force. The duration of exposure to the factor is also a variable to take into account for the development of MSDs, particularly the number of repetitions performed per day and the total exposure time (9, 29). The injuries are linked to excessive effort that in the short term produces acute lesions meanwhile in the long term generates chronic alterations when the self-healing and repair capacities of the affected structures are exceeded (24). The risk of suffering from MSD depends largely on the posture of the worker, especially if a limb or body segment is twisted or bent, which increases the possibility of the development of diseases and pain (14,30).

Individual and sociodemographic risk factors

These categories of risk factors are more variable and depend on the studied individual, among them we find gender, age, level of education, country of origin and presence of comorbidities (14). The role of gender as a risk factor for MSD has been shown not to influence significantly. However, it is evident that the distribution of work-related injuries is variable depending on the specialties and occupations where there is dominance of one gender or another. Differences in the distribution of work sectors may explain the discrepancies in exposure to ergonomic risk factors and the variations in the distribution of people affected by MSD. Similarly, risk factors will be more representative for women working in professions that are male dominated, because most of the work elements and tools are not anthropometrically adapted for them. Furthermore, it has been concluded that women are more vulnerable to suffering from MSDs due to the numerous psychosocial demands and the fact that they are segregated to informal, unstable and poorly protected occupations (31,32).

Regarding age, it is established that while older workers are more likely to present musculoskeletal symptoms in consequence to the decrease in their functional capacity, younger workers are more exposed to MSDs since they perform heavier tasks, work under pressure and often need to fulfil these orders more quickly because of a deadline. Low-educated and immigrant workers are at higher risk for MSDs because they tend to pursue more demanding, dangerous, and strenuous jobs (31, 33). On the other hand, according to the lifestyles of each worker, it is known that smoking increases the risk of presenting symptoms, on the contrary, the practice of some physical activity is related to fewer musculoskeletal symptoms since individuals with elevated BMI are 20% more likely to present pain in any part of the body. Comorbidities and past clinical history are important in the development of MSD, since the inadequate ergonomic practices contribute to the chronicity and exacerbation of previous injuries (19, 29).

ORGANIZATIONAL AND PSYCHOSOCIAL RISK FACTORS

The respective investigation concerning these factors is limited, this group includes the location and organization of the workplace and everything related to the rest cycle, work load and demand, type of activities performed, stress in the workplace, little control in the workplace, lack of support from supervisors and colleagues, and its emotional value and impact on psychological health as a risk factor for developing MSD (12).

Psychosocial risk factors that indirectly have an influence include demanding clients, time pressure, long and irregular working hours, and poor communication or cooperation (14, 29). Suffering from depression, anxiety, fatigue, tiredness and insomnia are also associated with discomfort in the lower limbs, upper limbs and back increasing at the same time absence from the workplace (12).

From what is mentioned above, depending on the member or place of the body studied, the association with different risk factors varies:

- Neck: heavy work, inappropriate positions, lifting, low support and job satisfaction, stress, advanced age, female gender, sedentary lifestyle, comorbidities, high BMI and smoking.
- Lower back: physical work, inappropriate, static or dynamic position, lifting objects, little control at work, decreased level of satisfaction, young people, female gender, black race, smoking, high BMI and comorbidities.
- Shoulder: heavy, repetitive work, stress, monotonous work, little control at work, advanced age, high BMI and sedentary lifestyle.
- Elbow / forearm: heavy work, improper position, static or dynamic, repetitive tasks, prolonged computer work, little control at work, high psychological demand and dissatisfaction, advanced age, female gender, high BMI.

- Wrist / hand: physical labor, improper position, static or dynamic, repetitive tasks, prolonged computer work, stress, advanced age, female gender, comorbidities, elevated BMI and smoking.
- Knee: demanding physical work, prolonged kneeling, bending or standing, lifting and carrying heavy objects, psychological stress, previous knee injuries, elevated BMI, smoking (7).

Risk factors on healthcare professionals

In the specific case of health professionals, they are one of the working sectors most affected by the problem of MSD. Those who work in surgical, intensive care, and rehabilitation settings have a higher risk of developing MSDs compared to those who work in community settings and private practices.

Professionals who work in awkward positions, who work in the same position for an extended amount of time, who must bend or twist anatomic structures, transfer patients, lift objects, perform monotonous or repetitive tasks, handle a large number of patients without the chance of breaks are at greater risk of injury (34).

In surgeons, static postures, uncomfortable positions, repetitive movements and the effort applied to operate is frequent. It is estimated that up to 87% of surgeons have work-related pain and manifest exhaustion in up to 40% (4,18). Similarly, around 45% of surgeons report neurological symptoms, and the numbers increase depending on the duration of the procedures and likewise the severity of the symptoms as well. With the arrival of minimally invasive surgery, new ergonomic challenges have been posed to healthcare personnel, especially surgeons due to the restriction in the degrees of freedom of movements that limit these specialists, forcing them to adopt postures and surgical movements that are not optimal for instance the static position of the head and trunk (4,18,21). They have also had to adapt to working under a two-dimensional image, while working in three-dimensional spaces. The previously mentioned conditions are aggravated by the influence of laparoscopic instruments inserted through fixed trocars, which require exaggerated movements to perform fine movements in the inner part of the body, which often causes a flexion of the wrist, exaggerated ulnar deviation and abduction of the arm to place the thumbs in the handles, which causes compression of the digital nerve of the thumb, causing paresthesia and neuropraxia, producing the lesion known as the "laparoscopic surgeon's thumb" (35). In addition, the height of the tables was established to perform open surgeries, which forces surgeons to use excessive abduction of the arms or to stand on platforms that are sometimes not high enough, this increases their cognitive and physical work load, resulting in the development of adverse symptoms (27).

The issues in surgeons are intensified by the need to change the settings for each operation, including the position of the monitor, patient, ports, and bed. Female sex, inexperience, and smaller gloves are cited as risk factors for the onset of symptoms (36, 37). Individuals with a small surgical glove size experience more difficulties while using laparoscopic surgical instruments, since the different sizes are not taken into account during their manufacture. Assistant surgeons also experience symptoms that tend to be more severe during cases with a longer duration. In the same way, a significant relation of workload or years of experience was found, increasing the appearance of symptoms (3).

Most frequent injuries

The WHO classifies injuries caused by exposure to ergonomic risk factors into two main types, one is acute and painful caused by a heavy, brief load that requires great effort, generating sudden failure of a structure and its function, for example muscle tear or fracture. Contrary to the above, the other type of injury is chronic and constant resulting from a permanent overload that leads to pain that progressively increases and generates dysfunction over time; this causes muscle spasms or ligament tears. The latter are the result of continuous work, hence are usually ignored by the worker because it is presumed that the symptoms will resolve and will not generate any type of disability condition. Generally, in the muscles, ligaments and tendons there are tears or ruptures, while in the bones the most common injuries are fractures, microfractures and degenerative changes. In addition, irritation at the insertion sites, functional restriction, and early degeneration may occur (9).

Regarding frequency of presentation, low back pain is the most common symptom (45.7%), followed by neck pain (28.5%), hip and thigh pain (7.1%) and shoulder pain (5%) (33). Low back pain is more common in jobs that involve intense manual tasks, awkward postures, repetitive work, computer work, and the application of excessive forces. For this reason, it is not uncommon to find it in health workers such as nurses, dentists, physiotherapists and surgeons, where the management of patients frequently involves the previously mentioned activities. At least one out of every two health workers reports back pain, and one of the clinical causes that explains its appearance is disc herniation which manifests as throbbing pain in the leg, hip, buttocks or a sensation of numbness (30, 33, 38).

The prevalence of MSDs among nurses varies between 60-80% in different body portions with a higher prevalence in the lower back (43%), this is related to activities carried out in their work such as lifting and transferring patients and working in uncomfortable and non-ergonomic positions (39, 40). Among dental workers, working conditions restricted by the oral cavity, prolonged sitting, uncomfortable positions with few rests and recovery exercises are decisive for the appearance of MSDs. This has a more significant impact and therefore a higher prevalence in the female gender and in periodontists (41-43). Physiotherapists are regularly vulnerable to risk factors for MSD more specifically low back pain. The exposure to lifting, movement and transport of dependent and incapable patients, work postures and the frequency and repetitiveness of the treatments carried out affect the worker causing the appearance of injuries before the age of 30 and around 5 years after the first exposure. The emergence of symptoms is also related to the tendency of young people to work in high-demand areas such as intensive care and rehabilitation units (38).

The management of patients can not only cause low back pain, it can also involve pain in the neck, shoulder and arms due to the load placed on these body parts, actions such as pushing and pulling are the main causes, although the precarious organization and work environment are mostly responsible for the worsening of the clinical symptoms. The most common disorders in the upper limbs include tenosynovitis, tendonitis and bursitis of the shoulder, carpal tunnel syndrome, quervain's disease, neck strain syndrome, thoracic outlet syndrome, frozen shoulder, lateral epicondylitis, and cervical spondylosis (44). In the lower limbs, the most frequent pathologies are hip pain, osteoarthritis, degeneration of the menisci in the knees, swelling of the lower limbs and appearance of varicose veins, in most cases produced by prolonged standing or sitting, where gravity and the weight that the patient must bear are the causal agents. Eye fatigue, limb stiffness and numbness are also recurrent symptoms (9).

Hand and wrist symptoms do not vary overtime, which can be explained by the active interaction between the hand muscles and the working instruments, which is why it is important to keep the wrist in a comfortable position. Unlike the first ones, the symptoms in the neck, shoulders and back are dependent on time, resulting from poor posture for an extended period; as well, constitutional symptoms such as irritability, headache and fatigue (25).

In surgeons who perform laparoscopy, shoulder symptoms are present in 78% of the cases; 66% report pain after long-term procedures and 44% report using analgesics. Pain is more frequent in those who perform minimally invasive surgery, than those who do open operations, correspondingly, there is the conception that minimally invasive surgery only has benefits for the patient, and that ergonomically there would be more benefits through the use of robotic surgery, although the difference in statistics of disorders is considerable, it is not very high (2, 19, 27). Procedural physicians, such as interventional medicine specialists, are at high risk for work-related MSDs. This is due to long working hours involving repetitive movements, static and awkward postures, and instrument design challenges, especially given the rapid pace of innovation in the context of an increasingly diversified workforce (44). Among surgeons, orthopedic surgeons generate an important load and influence on their bones and muscles, as a result to the magnitude of the procedures performed and the equipment implemented during their work; they manifest MSDs mainly in the lumbar area, hands and shoulders. It is more frequent in surgeons older than 55 years to be absent from work due to MSD, and 31% of them express having received a surgical intervention to treat work related injury (27).

The surgeons who most repeatedly perform minimally invasive procedures are endoscopists, gastrointestinal surgeons, oncological surgeons, urologists and gynecologists specialized in laparoscopic surgery, which is why the prevalence of MSDs in these groups is higher, exceeding 80% according to studies (45). In the field of plastic surgery, cervical spine disease is the most common MSD with a prevalence of 24%. In this group the most frequently reported areas of work-related pain were the neck (60%), back (57%) and wrists (19%) (27). In pathology and radiology, the use of microscopes and computers is a significant risk factor for MSDs in the neck, back, shoulders and upper extremities, prolonged use without breaks and poor ergonomics in the workplace can contribute to injuries. Because of their work, the use of ergonomic chairs is recommended to mitigate symptoms such as headaches, neck and back pain, as well as paresthesia in the hands. Some recommendations are the use of microscopes that keep the back in a neutral position and the use of digital screens for visualization. Eye fatigue caused by this equipment is also a significant problem (27). In ophthalmology, there have been observed prevalence rates of 39% for low back pain, 33% for upper extremity pain, 33% for neck pain and prevalence of up to 80% for back pain. 9% of ophthalmologists stop operating because of the uncomfortable or cramped positions and the postures that are adopted during surgery for extended periods of time. It is recommended to position the patient at the appropriate height and to develop ergonomic guidelines for ophthalmic equipment (27).

Tools for ergonomic assessment

With the goal of evaluating the ergonomic risks in a patient, tools and technologies are used in order to get to know different aspects. These instruments can assess ergonomy subjectively or objectively. Subjective tests are surveys and questionnaires, while objective tests are equipment that allow the measurement of work postures. Some instruments that have been used in surgical ergonomics research include the Body part discomfort (BPD) scale and National Aeronautics and Space Administration workload index (NASA-TLX), Another subjective assessment of ergonomics consists of direct observation of the worker in a video recording with one or several cameras during their work practice either live or simulated, which will then be analyzed under standardized scoring systems thus evaluating ergonomic performance. The commonly used scoring system is Rapid Upper Limb Assessment (RULA), which measures the risk of upper limb, neck, trunk and leg strain caused by repetitive movements and static postures. These results can range from one to seven points, with three or more indicating a possible ergonomic risk, and a score of seven indicating a high ergonomic risk requiring immediate intervention and modification. In the same way, the strain index (SI) that accompanies the RULA is used to assess strain risk and the Rapid Entire Body Assessment (REBA), which was developed to assess combinations of dynamic and static positions and load handling observed in healthcare workers. These scales are useful for understanding overall strain, however, all of them are exposed to a possible recall bias and discomfort reported by staff may not be related to demonstrable effects at the injured tissue, therefore they should be accompanied by objective tests, these include physiological parameters such as skin conductance, goniometry, kinematics with reflective markers that report joint movements, and electromyography that uses electrodes to measure action potentials in muscle groups (2, 4, 43).

Treatment

With the consequence of the appearance of MSDs, specific therapeutic aids are presented that are recommended under the advice of a professional in the field of ergonomics, which provides the necessary medical bases to achieve an appropriate assessment of postures during the common performance and practice within the workplace. However, healthcare personnel due to their demanding work context, prefer to modify their practice acting based on pain and self-medication by taking analgesics including non-steroidal anti-inflammatory drugs and muscle relaxants, and/or therapies, physiotherapy, massage, stretching or ultrasound; they resort to rest or simply ignore the symptoms, which justifies the under-reporting of injuries, thus healthcare professionals are more likely to take sick leave to treat an MSD than to report their injury and make an official claim (20, 46). Therefore, timely interventions within the area of prevention are needed to enable appropriate risk management and consequently prevent the occurrence of MSDs.

Prevention

The elevated prevalence of MSDs in healthcare workers, especially surgeons, justifies the need for timely intervention to reduce the occurrence of cases. Several potential areas for improvement have been identified over the years, including operating room layout, tool design and ergonomics training, but there is little evidence of improvement in the prevalence of cases; therefore, multifaceted interventions including healthcare attention, service coordination and work adjustment are now proposed to improve MSDs (34, 37, 47). The measures mainly studied are based on a program of management of the associated risks, device engineering, redesign of the work environment, education and training, with the aim of contributing to the development of a productive, healthy and long working career (24). It should be emphasized that a comprehensive approach to improve ergonomics, prevent injuries and enhance performance while ensuring the safety of surgeons requires prevention methods appropriate to the entire surgical team, easy to use and standardized according to each specialty, in order to optimize compliance and address the specific risks that cause MSDs. Furthermore, ergonomics should ideally be taken into account in all areas of life, including the home, the office and the operating room, by adopting proper posture on a regular basis, incorporating it into day-to-day activities (8).

It is recommended to avoid seven activities that contribute to the generation of MSDs such as: repetitions, defined as cycles of less than 30 seconds or the presence of a basic element of the activity that covers more than 50% of the total cycle; repetitive or prolonged effort of more than 30% of the worker's strength; activities with vibrating tools; maintaining body segments in an extreme position; prolonged posture; exposure to cold and combinations among the above conditions (2). Therefore, certain recommendations related to movement, relaxation and maintenance of ergonomics are established, such as:

- Maintaining good health, fitness and balanced nutrition by performing a series of safe and effective exercises outside the operating room to improve whole body health and strength (6,48).
- Perform routine stretches to improve flexibility and decrease the risk of MSDs (48).
- Practice good posture while working in an upright position, avoid leaning forward or sideways, trying to maintain a neutral position, relaxing muscles, aligning hips, shoulders and ears (49).
- Place the monitors in proper position, avoiding twisting or extension of the neck, it should be in a straight line and approximately 15 degrees below eye level, with the goal of avoiding neck injuries. In the preoperative period, it is important that the surgical team takes into account the medical purposes and foresees the possible intraoperative needs, carrying them out without physical overload. In addition, if necessary, the configuration of each operation should be changed, including the position of the patient, monitor, ports and bed for adequate visualization and access by the surgeon (28,49).
- Wear properly fitting, two-piece protective clothing, restraining its use in the procedure room and removing it in all other areas (49).
- Use a lumbar/abdominal support belt (49).

- Intermittently place one foot on a 15-centimeter block during long procedures (49).
- It is also useful to move and stretch during long procedures, our bodies are not made to maintain static positions. They should be easy to perform, should not require special equipment for their development, should not modify the surgical procedure and should be directed to the most painful areas. Likewise, it is important to maintain the ergonomic approach not only during the surgeries, but also after the surgery, it is necessary to concentrate on stretching the neck, shoulder and back in particular (8, 49, 50).

However, different studies have shown that physical interventions, especially in the form of regular breaks or standardized micro-stretching pauses, have been proposed as appropriate measures to protect both the surgical team and the patients, as they are considered necessary to interrupt static postures, maintain mental concentration and improve physical function by reducing muscle fatigue. It is recommended to assign five-minute breaks every half hour during the surgical process, improving communication between team members and therefore their performance by reducing fatigue, tension, pain, stress-related cortisol and testosterone hormone levels, decreased error rates and possible negative intraoperative events. In addition, there is no significant increase in operative time or patient care (4, 8, 25, 51-53). As a result, it is necessary to implement a proper program in ergonomic education starting from the academic training given during college studies, increasing awareness on the subject in future medical professionals, as well as the implementation of didactic talks on the topic and the use of media as a way to demonstrate what the correct ergonomic behavior of professionals at work should be, thus helping measure the postural angles and identify areas of improvement to be made from the ergonomic point of view. It should be emphasized that this should go hand in hand with the optimization of the workstations and the use of tools that contribute to improve the body posture during the surgical procedure, minimizing physical tensions (8, 22, 27, 35). In the same way, rotation is used as an ergonomic tool for the improvement of the working conditions, avoiding the isolation of a worker in a demanding working station. This strategy is effective because it diversifies the working places and decreases exposure and overload (9).

Future directions

The high prevalence rates of MSDs among healthcare personnel suggest the need for more effective interventions to efficiently reduce the associated ergonomic risks. However, there are several factors that may be responsible for the limited number of prospective studies on the subject, one of them being the difficulty of introducing external research personnel into the operating rooms, affecting the usual operational flow; in addition, these studies usually measure subjective parameters such as pain, mental stress levels and fatigue, which may hinder opportune evaluations. Therefore, it is first necessary to accurately identify all the hazards and risks faced by healthcare workers during their work practice, especially surgeons, counting with the indispensable collaboration of experts in ergonomics and occupational medicine, allowing the development and examination of a more comprehensive approach using biomechanical tools such as motion analysis and electromyography systems, with the aim of developing instruments for the measurement and improvement of ergonomics in surgery, taking into consideration important characteristics such as ease of use, objectivity and specificity according to each specialty, and consecutively, should be directed to the entire surgical team through the implementation of evidence-based ergonomic training protocols to protect staff from preventable injuries that may affect their productivity, well-being and the longevity of their career contributing directly to patient safety (2, 17, 18, 44).

Conclusion

MSDs are considered a global health problem due to their high prevalence in workers in different labor sectors, especially healthcare personnel because of the ergonomic challenges they face daily in their practice. Although various ergonomic interventions have been established and applied over the years, the expected impact on the reduction of cases has not been achieved due to the limitation of the tools used based on the collection of subjective data, the use of recording devices that are difficult to operate and the poor correlation between subjective reports of injuries and objective results. Like all other workers, healthcare workers and especially surgeons have the right to practice their profession in a safe environment that does not affect their health in the short or long term, and that will prematurely decrease their productivity, workload and career longevity. Therefore, further research is needed to precisely define the specific ergonomic risks according to each medical specialty, in order to carry out a more suitable risk management alongside with an effective implementation of early ergonomic education programs, which will create greater awareness in healthcare personnel about the importance of taking care of their health and indirectly of their patients.

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Chapter 8 Ergonomics and Neurosurgery- An Introduction

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LEARNING POINTS

After reading this chapter, the reader will be able to

- Explain the effect of the Work–related Musculoskeletal Disorders.
- Determine the proper ergonomics for the multiple neurosurgical instruments.
- Recognize some specific ergonomics for the operating room.

ABSTRACT

The Intensive Care Unit and Critical Care are part of the most challenging current medical practice levels. It is in this environment where the physician (and all the members of the critical care group) helps the patient into the course of the illness, whether to have a proper death or to surpass the disease and get an adequate improvement to continue with optimal health status (when it is possible). These units are one of the most important facilities that a hospital must consider, and the medical attention will be focused on very few patients compared to other departments. However, it is here where life or death is "decided". All the critical care members work 24 hours and seven days a week, with long shifts to improve the patient's management, sometimes the personnel is not enough, or maybe the workplace and workload might not be the correct one. The present chapter discusses an overall presentation on the factors that might affect the intensive care units' proper ergonomics. Simultaneously, considering that when these are correct, the beneficial effect will be to the medical staff and the patients due to a better physical, emotional, and mental health of the personnel that will lead to better attention and treatments.

INTRODUCTION

Neurosurgery is one of the most amazing medical specialties for those who admire the brain and want to be in the Operating Room (OR). Neurosurgical procedures have been over human history since ancient times with the beginnings of the Decompressive Craniectomy (DC) (a procedure that was used from the time of the ancient Egyptians and Romans). The neurosurgery history includes several descriptions of many functions performed against the odds while improving patients' outcomes. It all began with trephination (even without knowing the purpose for this). In the past of times, multiple and several improvements have been made in the neurosurgery environment to achieve better patient outcomes. Neurosurgery is characterized by procedures that could take several hours; a surgeon could spend a mean of 22 hours per week in the OR. During the last decades, less invasive techniques were created to minimize the tissue trauma during the surgery; still, these changes lead to a relatively complex OR environment that needs to be very comfortable for the neurological surgery team to get the *most possible better results*. These approaches put a more physical and mental strain on the surgeon.

The issues of ergonomics in surgery are usually ignored, especially because the "*physician culture of teaching,*" there is not a focus on these topics during years of training; the focus of health care is only on the patients and the possible outcomes rather than on the well-being of the physician. The usage of forceps, microscopes, a correct sitting position, awake-patient surgery, endoscopic approach (or whatever other instrument or approach that might be useful for neurosurgery), must include optimal ergonomics for the surgery team. When these criteria are not fulfilled, it could lead to Work-related Musculoskeletal Disorders (WMSDs) (defined by the World Health Organization) as health problems of the locomotor apparatus that go from mild disorders to transitory disorders and could be irreversible and disabling). It might affect the surgeons' career, life quality, and health. The estimated compensation cost due to the lost workdays for WMSDs is around $20 billion annually without considering the indirect cost that could rise to $54 billion approximately.

NEUROSURGICAL INSTRUMENTS

During the surgical interventions, multiple tasks are involved (incising, drilling, dissecting, retracting, dilating, suturing, and some others); also, the environment inside the OR could determine the intervention quality and the outcomes. When these do not fulfill "the ergonomics criteria", the neurosurgical instruments will lead to WMSDs, muscle fatigue, discomfort, affect the surgical procedure, and even reduce the surgeon career length. The usage of long and rigid instruments could exacerbate hand tremors; also, these decrease the tactile feedback leading to a more challenging dissection of the critical structures; because of the smaller grasping surface and the instrument characteristics, more force is required to grasp them and use them steady.

Optical technologies are part of the neurosurgery evolution; since 800 BC the magnification has been used, but until the 20th century, the microscope was introduced in surgical procedures. Since the '60s the neurosurgeons began to formally teach microscope techniques, including light system and maneuverability. Simultaneously, it began the usage of endoscopes (neuroendoscopy was initially related to the hydrocephalus treatment). The endoscopy approach improves the surgeons' ergonomics while enhancing comfort and reducing the physicians' fatigue. However, the endoscope needs to be placed close to the intracranial structures, but this will limit the usage of instruments near the scope due to the frequent fogging and obstruction of the lens (by blood and tissue).

The exoscope (a high-definition extracorporeal telescope) was developed in the last decade, and it has been improving the ergonomics in the OR because it is easier to set up, it has a wide/larger working distance, and it has a broad field of view with greater mean focal distance compared to the endoscope. The advantage of the exoscope is that the surgical assistant and the neurosurgeon get the same field of view, and everyone in the OR can follow the procedure (something that is very helpful in the university and teaching hospitals) and permits efficient usage of surgical instruments.

The wearable head devices could be beneficial in saving time in the OR. The Augmented Reality (AR) is part of medical education and surgical training. Nonetheless, there are some drawbacks for these, the size of the screen (that is quite small) and the asthenopia (eye strain) while concentrating on the small display for prolonged times could reduce the ergonomics of the device (something that is also applied to those traditionally used medical imaging monitors). Even though the usage of this mounted device reduces the time that the surgeon spent rotating his/her head while looking at the monitor and clearly, reduce the exposition time to radiation, surgical time, and muscular fatigue.

Usage of the microscope

The microscope has represented a mainstay for neurosurgery since the last century. Operating a microscope in the OR is part of the integral surgical approach nowadays. Before its usage, all the other general instruments were used, but with microscopic neurosurgery, several instruments came to improve multiple interventions, and the microscope laid the foundation of micro neurosurgery. The naked human-eye can distinguish two discrete lines separated by 0.2mm; when the lines are closed, the perception became of a single line; with the microscope, the human ability to resolve these objects and appreciate with more detail anatomical structures are highly increased. The microscope revolutionized neurosurgery with its specific advantages (better illumination, coaxial vision, and magnification); these characteristics have increased the surgeons' welfare and improved surgical ergonomics. The use of microscopes sometimes requires operating with outstretched arms, which will produce muscle fatigue in a short time even if there is an armrest.

One of the main complications regarding the ergonomics of the microscope usage is to handle it with one hand; this requires some extra-force when gripping the operating handle to swing the axis towards the surgeon and the lateral or medial displacement when needed. Some surgeries that require a static neck flexion (that will aggravate the pain and fatigue as the surgery time extends due to the prolonged visual focus), the WMSDs risk is highly increased. Some authors establish that the operating table height elevation can improve these adversities. However, the visualization of the surgical field and surgeon position might be affected by this change. When using a microscope, the neurosurgeon has a neutral spine position reducing the risk of inadvertent neurological and neck injuries, making the procedure safer not only for the patient but also for the surgeon. In some semi-sitting positions, the microscope has not been well received because of the need to perform fine dissection in deep and narrow structures while encompassing the voluminous microscope.

To avoid some of the cumbersome and tedious situations of using the microscope during surgery, the mouth switch (a mouth-piece to handle the microscope) was created. Nowadays, it is an indispensable part of the surgical instruments to promote operative efficiency; it is important to keep in mind that the microscope should adjust to the surgeon position and not otherwise with the surgeon adjusting the focus and ocular position every time after each movement, because this, will lead to repeated interruptions, the need of reorganizing the ideas and affect the surgery workflow or fluidity; something that will end up in some inefficient long-operative times. The hand-tremor and fatigue are related to the arm muscles' overuse to stabilize it.

Micro-instruments

According to the literature, initially, the micro-instruments had straight arms to provide more precision and ease the manipulation, but these obscure the visualization of the tips when reaching the structures; for this reason, a bayonet shape-like instruments with down-scaling size, comfortable grips, and fine pointed tips were created.

These helped perform different tasks during the surgery and allowed us to visualize deep structures regardless of a narrow surgical path. Micro-suturing is used in the daily routine for the skin and dura closure as well as for nerve and vessel anastomosis; the instruments used in the OR for this are the dissecting scissors, micro-forceps, vessel clamps and dilator, and needle holders.

Micro-forceps

The micro-forceps are useful for tissue handling, sutures, and holding the needle. Notwithstanding, the micro-forceps ergonomics could not be the best for the surgeon due to the enlarged distance appearance when high magnification is made by the microscope and a higher applied force required for its usage.

Head-mounted display

Currently, for the minimally invasive procedures in neurosurgery, neuronavigation became an essential tool that maximizes the safety of the intervention; nevertheless, its ergonomics might be considered “sub-optimal”. The surgical pathway is characterized most of the time by deep, small, and narrow corridors surrounded by critical structures (nervous or vascular); the surgeon is usually forced to "develop X-ray" across the anatomy during the surgery due to the limited perception of the surgical field.

In the last published manuscripts (date of this chapter creation), the introduction of an AR-based neuronavigation was suggested by some authors. One of the main disadvantages or difficulties of the ergonomics and effectiveness is the visualization modality employed in the different specifical surgical tasks or the lack of a focus. AR-Neuronavigation models might increase the surgery ergonomics if an accurate display is achieved with more studies and technology improvement. This will help minimize surgical errors like spatial-relationships and surgeon eye-hand coordination.

The Head-Mounted Display (HMD) is used in neuro-endoscopic procedures; according to some studies, it has been improving this approach ergonomics and surgical time by allowing a neutral head position and reducing the ocular fatigue and visual strain in the surgeons.

Foot pedals

There are multiple types of pedals and are used for different functions like cautery, drilling, microdebrider, and irrigation. The pedal usage's main issue is that these are obscured from the surgeons' direct vision making it necessary to look down to locate the pedal. There are some recommendations for the usage of pedals that will be discussed ahead in this chapter.

Operating Table and Surgical Stool

An inadequate height would lead to a long-time neck or spine flexion, increasing the surgeons' discomfort and fatigue. It is important to have an adequate table height. According to some recent studies, it has been recommended to place the operating table height at a midpoint between the sternum and the umbilicus; this will reduce the long-time spine, trunk, and neck flexion exponentially.

Robotic surgery

The da Vinci Robotic Surgery has been widely used in different surgery areas and has provided quite improvements during diverse interventions, it has 4 arms that can be used to precisely perform delicate operations regardless of the narrow, or the deep of the tissues and structures, the 3D-HD images and the digital zoom along with the angle of view and the arms mobility and flexibility are one of the most admired things of this type of surgery, as well, it has an anti-shake feature that will be quite efficient when operating around critical structures. This system increases the ergonomics because the surgeon is comfortable seated and manages the arms with the proper calm. Yet, there is still a need for more research studies and technological improvement to ensure if it is useful for neurosurgery implementation.

REGARDING THE SURGEON COMFORT AND ERGONOMICS

As previously mentioned, a bad ergonomics environment will lead to WMSD's but also reduce the life quality and career length of the surgeon. The increment of lost-workdays due to workplace-related emotional or physical stress is one of the major causes of less productivity among physicians and especially surgeons globally. It is not a secret that regardless of the years of clinical practice and preparation, sometimes, a load of responsibilities, emotions, mental worries, or even physical endurance during a procedure could lead to taxing and debility that could lead to a burn-out syndrome. Also, it is important to consider that when the OR environment and ergonomics are not the best, it could lead to a stressful environment with unfavorable outcomes due to distractions and decision-making issues that affect the surgery human-element.

Debility and musculoskeletal disorders among spinal surgeons

In the daily medical practice (and even during the medical education years), there is a 'philosophy' of *ignoring one's problems and discomfort in the quest to give the best for the patients*; this is something that applies more often to the surgeons life.

When the surgeon has the patient on the table, a self-imposed commitment to patient care leads the surgeon to ignore their limitations and debilities to achieve the expected outcomes after the intervention.

Table 1. Recommendations to reduce the risk of WMSDs and improve OR ergonomics.	
Operating Table	It has been evidenced that when increased the height to the midpoint between sternum and umbilicus while keeping the hand in line with the elbow at 10 cms accompanied by an internal abduction and rotation of the arm, muscle fatigue and WMSDs risk is highly decreased.
Utilization of Loupes	Coupled to the operating table height will simulate a natural position reducing the muscle and spine strain and fatigue.
Using the Microscope	According to some recent data, it has been suggested to be more ergonomically than loupes and headgear. When working with arms held forward, flexion of the elbow joint can increase comfort and reduce muscular fatigue, especially when working with outstretched arms. A comfortable chair and a slight recline can relax the muscle, with an armrest and the arms slightly extender but not stretched can stabilize hands and reduce muscle fatigue
Monitor placement	The monitor should be placed at 100 cms approximately (from 80 - 120 cms) away and in front of the surgeon and should allow straight view beneath the surgical field.

Foot Pedals	It has been suggested that the surgeons should minimize hovering foot pedals and the use of those instruments that require the pedal. However, considering that this might be difficult, some studies suggest using a large-padded mat to avoid pedal drifting and increase the surgeons' comfort.
Surgeon Position and Pos ture	Soundness (either Sodium or Magnesium) – 5 cycles
Patient Position	Depending on the type of surgical approach, some recommendations have been made, in the case of a sitting position some authors recommend the following: 1. Proper patient head positioning with the horizontal axis of tentorium less to 90° and parallel to the floor with the surgeon axis. 2. Incline the head to 25° approximately by leaving a 2 fingers distance between the chin and the sternum to avoid spine lessons and elevate the patient's upper torso so the surgeon can use the patient's arms and shoulders as support. 3. Maneuver the microscope with the mouth-piece.
Endoscopic Instruments	It should be multifunctional, adjustable, and easy to use with low muscle activation and reliable force. The proper contact area and insertion angles might reduce the muscle load.
There are special features to consider in the OR and the surgical practice for the neurosurgeon.	1. Position and postural ergonomics. 2. The OR environment (from operating table, chairs, monitors, light, and navigation to the other instruments that might be useful in the procedure). 3. Instrumental design and the usage of technologic instruments.

	4. Operating list, length of the different procedures, the more ergonomic position, and the needed instruments. 5. Try to avoid being overwhelmed by the intensity of the case or the OR stress; try to preserve your energy and concentration, especially on the surgery's critical parts. 6. Good lifestyles and frequent exercise. 7 Good practice and constant self-improvement made a successful and competent surgeon.

One of the most stressing demanding procedures is related to spine surgery; over the years, the different approaches have evolved, but the levels of debility and stress have also increased within these procedures. During the operative day, the back pain increases gradually because the surgeons adopt a posture through several prolonged time. Especially a lumbar flexion posture or, in some cases, a sustained standing non-neutral position with long time neck (hyper) flexion and coronal misalignment; in other cases, the surgeon position is static leading to stiffness and pain that would be present even after several hours after the procedure. Surgeons are at high risk of suffering from WMSDs; the neck's sustained flexion is necessary during multiple procedures, even though surgeons often neglect this posture and symptoms due to the need for full concentration during the surgical intervention.

Due to the repetitive activities and movements (i.e., squeezing and grip moves) related to some surgical tools, hand problems could be quite often, especially in older surgeons. Some disorders (that affect muscles, nerves, and tendons) are tendonitis, degenerative spine disease, tension neck syndrome, carpal tunnel syndrome, or hand dysfunction; these are caused by repetitive strain injury and hand movements.

It has been evidenced that surgeons' have a higher risk of suffering from carpal tunnel syndrome when compared to non-surgical medical professionals. Neck, shoulders, and back complaints; are more frequent for those in the surgical practice. Also, it has been reported radiculopathies with leg or neck pain and finger, wrist, or elbow pain associated with the surgeon's practice. According to some recent data, lumbar discectomy, endoscopic third ventriculostomy, spine surgery, and ventriculoperitoneal shunting are the most related surgical approaches as preceding factors for those complaints.

FIXING THE PROBLEM

To fix these conditions, some specific recommendations have been made in the last decade to reduce the physical burden (please see Table 1). Some studies indicate that three special key-points must be considered during the intervention that will reduce the risk of suffering from WMSDs, these are 1. Avoid inclining the head forward; this will reduce the weight on the neck and the physical burden, especially in those long-hour procedures; 2. Avoid the pelvic griddle asymmetry; when we increase the weight on one side of the body, the muscle fatigue will be worst, and the uncomfortable and constant changes of posture would affect the surgeon skills; and last but not least, 3. Improper shoulder elevation or rotation would cause more early fatigue due to needless movements during the surgery.

CONCLUSIONS

Every job has its burden (mental or physical); there is a high risk of suffering burn-out syndrome in medicine, but depending on the specialization, there is a risk of some specific burdens. For the surgeons, there is a high likelihood to suffer from WMSDs. The main disadvantage is that during the medical training years, the ergonomics issue is quite underrated, and the physician often ignores his/her issues and discomfort while trying to alleviate other problems; this will increase burn-out and lower career satisfaction. The neurosurgeons use a lot of instruments during different procedures that take several hours; during this time, the discomfort and pain increase and will end up in WMSDs that could bring consequences as serious as the shortening his/her career, disabling injuries, life quality, and professional satisfaction decreased, among others. Any formal attention to the ergonomics during the neurosurgeon's formative years seems to be absent. Trainees and mentors should be aware of the WMSDs risk and develop awareness while improving the surgical skills and techniques during and after the training years. As well, it is essential to recall the importance of good lifestyle habits—especially constant exercises and workouts to train our muscles and reduce muscle fatigue and future WMSDs related injuries. The lack of ergonomics principles could be a silent epidemic in the OR; we must pay attention to it and establish some standardized protocols that help the surgeon keep his/her well-being. Nowadays, new technologies and recommendations are being developed to optimize OR ergonomics. Remember that before treating a patient, you might heal yourself first.

KEY POINTS

- Regardless of the "culture of teaching", we must recognize that we need to be in optimal health conditions to give the best possible health care delivery and surgical treatment.

- A proper surgical table height will reduce neck and back pain.
- When acquiring new surgical instruments, we should review the style or design to assess their ergonomics.
- When possible, when using the microscope, it is important to use a mouth-piece to handle it in a better way and reduce position changes and surgical time.
- Position the patient so that the surgical approach will lead to better visualization and more comfortable posture to improve the surgeon's ergonomics.
- Improving the ergonomics will reduce the WMSDs and medical errors while improving the surgeon and patients' comfort.

Suggested readings

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Chapter 9

Philosophy and Ergonomics of Operating Positions in Microsurgeries

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ABSTRACT

Microsurgery refers to the set of surgical procedures that are performed on microscopic structures of the human body, and for which the use of special instruments is required in order to increase the surgeon's field of vision, allowing to perform an optimal approach in the intervention. There are many medical specialties that currently use microsurgery in their field of work, including orthopedic surgery, maxillofacial surgery, ophthalmic surgery, vascular surgery, trauma surgery, among others. Microsurgery has been so widely accepted among surgeons that today it is considered an indispensable technique in fields such as plastic and reconstructive surgery. Microsurgeons must acquire complex surgical skills, as well as tolerance and self-discipline in order to be able to withstand long working days in the operating room, since as the hours go by, muscular fatigue and mental fatigue appear, which can contribute to poor surgical results and directly affect the patient's quality of life. In view of the increasing incidence of musculoskeletal disorders in microsurgeons, the concern of both health personnel and ergonomists has increased. Based on the above, the objective of this chapter is to present evidence regarding the philosophy and ergonomics of operating positions in microsurgery.

Introduction

Microsurgery uses of special instruments is required in order to increase the surgeon's field of vision, allowing to perform an optimal approach in the intervention (1). There are many medical specialties that currently use microsurgery in their field of work, including orthopedic surgery, maxillofacial surgery, ophthalmic surgery, vascular surgery, trauma surgery, among others (2,3). Microsurgery has been so widely accepted among surgeons that today it is considered an indispensable technique in fields such as plastic and reconstructive surgery (4). There are several differences between surgery and microsurgery, for example, as mentioned above, the latter employs complex techniques that require specialized instruments such as magnifying glass, surgical microscope, headlights, among others. Since the techniques used in both types of surgery are different, each one has its own benefits and warns of its own risks for both the patient and the personnel in charge of performing the surgical act (5, 6). One of these risks is the appearance of injuries at the muscular level, pain and affectation of the health professional's physical and mental health.

The Center for Disease Control and Prevention defines work-related musculoskeletal disorders as those injuries or disorders of the muscles, nerves, tendons, joints, cartilage, and vertebral discs in which the work environment and job performance contribute significantly to the development of the condition, or in which the injury persists or is aggravated by the working conditions (7, 8). Some work-related pathologies are tendinitis, carpal tunnel syndrome, degenerative spine disease, tension neck syndrome, among others. There are many factors involved in the onset of musculoskeletal disorders, including physical factors (poor posture, lifting, carrying heavy loads and performing repetitive movements), psychological factors, organizational factors and factors intrinsic to the individual. In general, musculoskeletal injuries occur more frequently in the upper limbs, and the main symptoms are pain, swelling, limited range of motion, loss of strength, burning and tenderness. Failure to treat these symptoms in time can lead to long-term work disability and personal dissatisfaction (9-11).

Association of surgery with the development of musculoskeletal disorders.
Ergonomics is the process by which workplaces, tools and systems are designed or organized to adapt to the characteristics of the workers who use them. Therefore, it refers to the interaction between the person and the work equipment, and the subsequent interaction that this can exert on the person (12).

Ergonomists have analyzed the surgeon's working conditions and have determined that they are similar to those of certain industrial workers; this statement is substantiated by studies that have reported a higher prevalence of musculoskeletal disorders in health professionals compared to the general population (11). This may be due to the altruistic mentality that has been embraced by most physicians who, in most cases, prefer to adapt to the patient's condition and the type of surgery he/she needs, often sacrificing their comfort as surgeons and acting against ergonomic principles (13, 14). Surgeons are usually exposed to great physical and mental demands of surgery, in addition to the pressure that can be generated by society and the time that is always against him/her; the grouping of these factors can contribute to the development of musculoskeletal injuries, which affect productivity and put patient care at risk (15).

Operating room personnel are very prone to present musculoskeletal disorders, especially surgeons, and this situation is so frequent that it is already considered a characteristic of the profession (16). Among the risk factors of this personnel, we have the performance of long working days in static position, the use of fast, fine, subtle and repetitive movements in their surgical techniques, the difficulty in the correct visualization of the surgical field which they "solve" with head and neck positions inclined forward to obtain a better visual field, manipulation of surgical instruments, social pressure and the impractical distribution of the operating room (9,17-19).

Studies have shown that between 50% and 85% of surgeons in various specialties experience work-related musculoskeletal symptoms at some point in their careers (20, 21). Forty percent of surgeons report musculoskeletal discomfort due to their workload and only half of them seek treatment when the injury has already become an impediment to continue their working life and they need urgent treatment. Failure to pay timely attention to musculoskeletal injuries can result in lower surgical attendance, absenteeism, early retirement and a general deterioration of the working environment in the operating room (7, 18, 22, 23). The appearance and localization of musculoskeletal disorders in surgeons is due to factors related to the type of surgery, among which we can say that the main ones involved are the ergonomic configuration of the operating room and the posture used by the surgeon during the procedure, followed by other factors such as the duration of the surgery, the equipment used in the surgery and the type of procedure to be performed. Over time surgeons suffer more consistently from neck, back and shoulder pain associated with their profession (24,25).

Impact of microsurgery on the incidence of musculoskeletal injuries

Microsurgeons must acquire complex surgical skills, as well as tolerance and self-discipline in order to be able to withstand long working days in the operating room, since as the hours go by, muscular fatigue and mental fatigue appear, which can contribute to poor surgical results and directly affect the patient's quality of life (26). The most frequent areas of appearance of musculoskeletal disorders in microsurgeons are the lumbar area, trunk, shoulders and neck **(Figure 1)** (27).

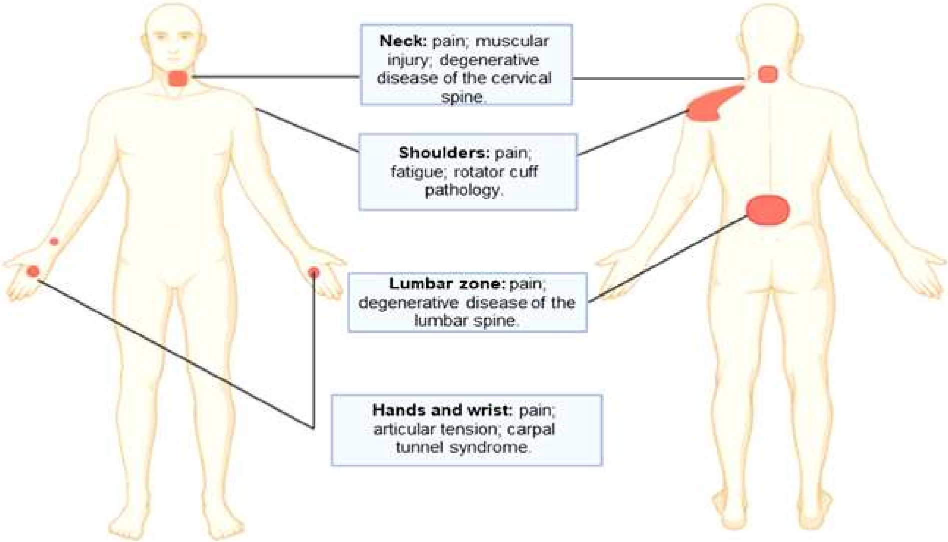
Neck: pain; muscular injury; degenerative disease of the cervical spine.
Shoulders: pain; fatigue; rotator cuff pathology.
Lumbar zone: pain; degenerative disease of the lumbar spine.
Hands and wrist: pain; articular tension; carpal tunnel syndrome.

***Figure 1**. Pain points and most frequent pathologies in microsurgeons*.

Due to work positions, instruments used, long working hours, among other factors, musculoskeletal symptoms and diseases occur more frequently in these anatomical regions (11, 27). Created with **BioRender**

In microsurgery, the microscope is used for procedures in which a high magnification is required, but the use of this device implies a static posture of the neck for a prolonged period of time, which can lead to fatigue and a greater risk of developing long-term musculoskeletal injuries in surgeons (28). The most frequent injuries associated with the use of the microscope are in the neck and upper joints (9, 27, 29, 30). In order to perform microsurgery, the surgeon must remain in a standing position for most of the duration of the procedure, since the structure of the operating room table prevents the surgeon from sitting properly, a factor that directly influences the appearance of musculoskeletal disorders in the surgeon (30).

When a person works in an awkward position for a long time, they will need to exert more effort to complete the task given to them, thus increasing the load and muscle tension, which can lead to overwork injuries in the long term (31). Similarly, microsurgery is dominated by the use of subtle and delicate movements for which the surgeon must use his intrinsic hand muscles, but the constant use and repetitive movements that fall on these muscles can also lead to injuries (6).

Most microsurgeries require the use of magnification and illumination tools to improve the surgeon's precision, and in some specialties these elements have gone from being an option to becoming a standard requirement; the use of these tools brings benefits to surgery but the price to pay has been the surgeon's health, since the use of these devices has been associated with the appearance of lesions and exacerbation of symptoms.

For example, the use of surgical loupes brings benefits in surgery as it provides an increase in the surgeon's vision, allowing him to appreciate even the smallest details of the tissues and to have greater precision of the instruments used, but studies have shown a consistent association between the use of loupes and headlights with the occurrence of cervical musculoskeletal disorders in microsurgeons. James et al (32), demonstrated that neck pain among spine surgeons who constantly used both headlamps and magnifiers was frequent. The use of magnifying glasses and headlamps involves a posture of flexion ≥ 45° and an inclination of 15°-30°, these postures result in greater stress load to the cervical spine which increases the risk of developing this type of injury and accelerating degeneration over time (33). In a similar way, surgical microscopes force the surgeon to fixate on the optical eyepieces, adopting an unfavorable position, which reduces comfort (30).

Most frequent lesions in microsurgery by specialty

Any health personnel can suffer a musculoskeletal injury, however, in the field of medicine there are many specialties that have a higher risk of suffering them, due to the workload and complexity that make it difficult for them to maintain good physical health. Among these specialties are dermatology, gastroenterology, general surgery, gynecology, interventional radiology, neurosurgery, ophthalmology, orthopedic surgery, otorhinolaryngology, plastic surgery and urology (11). In this section we will focus on the musculoskeletal disorders that most frequently occur in surgeons performing microsurgical procedures, who use microscopes or loupes in procedures that require high magnification, for example, to observe small caliber vessels during finger reimplantation (30).

Plastic surgery: Among surgical subspecialties, plastic surgery reports the highest prevalence of chronic musculoskeletal pain, injury and fatigue (34). Among the symptomatology involved are muscle tension, neck pain, low back pain, vision changes, shoulder arthritis/bursitis, as well as carpal tunnel syndrome and epicondylitis.

It is surprising that from the beginning, specialists and residents present symptomatology related to musculoskeletal injuries. Kokosis et al (35) conducted a study in which a survey was sent to all plastic surgery residents enrolled in accredited training programs in the United States to assess the presence of musculoskeletal symptoms and their predictors. They found that 94% of the residents surveyed had experienced musculoskeletal pain during surgery, with the neck being the most affected area; in addition, 89% of the respondents acknowledged having poor surgical postures, which is related to the occurrence of such disorders. The above may be explained by the fact that plastic and reconstructive surgery residents, during their training, spend most of their time using the microscope and may be highly prone to develop musculoskeletal disorders due to the excessive use of this tool, maintaining static and uncomfortable positions for many hours a day (12).

Khansa et al (36) conducted a study with the aim of estimating the prevalence of musculoskeletal injuries in plastic surgeons in countries such as the United States, Canada and Norway, to identify the factors and behaviors that could be the cause of these disorders, and to suggest possible solutions. They found that approximately 78% of the plastic surgeons surveyed had musculoskeletal symptoms such as pain, most frequently in the neck, shoulders and low back. They mentioned that the most common causative mechanisms for this issue were long duration of surgery, tissue retraction and prolonged neck flexion, citing solutions such as strengthening and stretching exercises, and adjusting the height of the operating table.

Orthopedics: Two-thirds of orthopedic surgeons have reported suffering musculoskeletal injuries associated with their work at some point in their career (37). In comparison to general surgeons, orthopedic surgery specialists have a higher incidence of musculoskeletal injuries over time. Every day these specialists are exposed to numerous risk factors such as chemicals, radiation exposure, physical injury and noise, which increases the jeopardy of injury. In the operating room, long days in the standing position and the handling of surgical tools further increases this risk. The predominant symptoms in this guild have been presented in the neck, upper extremities and lumbar area (38-40). In orthopedics, tools such as the X-ray protection apron are used, which have been associated with frequent and severe back pain even in young, healthy surgeons (41). The following musculoskeletal disorders commonly occur among orthopedic surgeons: low back pain, wrist or forearm tendinitis, lateral elbow epicondylitis, plantar fasciitis, carpal tunnel syndrome, among others, due to repetitive movements, standing for prolonged periods of time and the lack of knowledge about ergonomic aspects in the operating room (42).

Oculoplastic surgeons: These surgeons perform procedures in prolonged static postures without head and arm support, which can be uncomfortable, and often use surgical loupes or head lamps, these being predisposing factors for the development of injuries mainly in the cervical spine. Sivak-Callcott et al (43), conducted a study to determine the risk factors associated with pain related to the practice of ophthalmic plastic and reconstructive surgery, and found that 9.2% of ophthalmic surgeons surveyed who frequently used magnification by loupes or microscopes stopped operating due to neck pain. On the other hand, slit lamp biomicroscopy and indirect ophthalmoscopy are also associated with high muscle tension at the level of the upper trapezius and deltoids (44).

Otorhinolaryngology: This group of specialists is characterized by the presentation of chronic back and neck pain due to the ergonomic risk of remaining in a static posture either in a standing or seated position for prolonged periods of time, bending during endoscopic sinus surgery and panendoscopy can increase the risk of neck and back pain. The parts of the body most commonly associated with musculoskeletal injuries at work in the otorhinolaryngology department are the neck, back, hands and wrists (45). Otorhinolaryngologists during microlaryngeal surgery adopt uncomfortable working postures based on their training and personal preferences, ignoring ergonomic principles, preferring postures of neck flexion or extension, high degrees of adduction or abduction of the shoulder girdle and an inadequate position of the upper extremities during the procedure; maintaining these postures for a prolonged period of time leads to muscle and joint fatigue, pain and a considerable risk of musculoskeletal problems in the back, neck and/or upper extremities. Using an appropriate chair can minimize the degree of angulation of the surgeon's head (46).

Vascular surgery: Vascular surgeons are subjected to high levels of physical and psychological stress. A large proportion of these surgeons use magnifying glasses and lead aprons which contributes greatly to the musculoskeletal problems of this profession (47); 15-pound lead aprons can exert approximately 300 pounds per square inch of initial pressure on the intervertebral disc, thus increasing strain (48). Most of these surgeons report severe pain at the end of a day's work, which is significantly more severe in the lumbar area, in many cases becoming chronic pain (49). On the other hand, specialties such as interventional radiology make great physical demands such as standing for long periods of time, wearing heavy protective clothing, performing complex procedures, moving equipment and changing positions in order to perform their work (50). Pain occurs most frequently in the lower back, neck and shoulders. Prolonged standing with little opportunity for rest and awkward postures tend to aggravate back pain (51). The use of protective aprons against ionizing radiation increases the axial load and may aggravate low back pain (50).

Surgical ergonomics guidelines, procedures and new innovations

As mentioned above, there are many factors that can negatively influence surgeons' comfort as well as their ability to complete surgical procedures (30). These include musculoskeletal pain generated by poor positioning, as well as fatigue and discomfort related to long working hours in the operating room (30). This is why to avoid any type of injury, control operator fatigue and obtain better results, it is essential that the surgeon has confidence, comfort and a relaxed body posture when performing all types of microsurgical movements (26); these characteristics are very important especially when several hours have already passed since the beginning of the surgical procedure and fatigue could interfere in the operator's decision making and actions, so these aspects must be taken into account so that the surgeon can continue the surgical act with the minimum possible errors (26).

A study by Howarth et al (33) reported that injuries to the musculoskeletal system negatively influence several spheres of the microsurgeon's life, affecting posture, quality of sleep, interpersonal relationships, ability to concentrate, endurance and surgical speed. In an effort to prevent this type of situation and improve the quality of life of microsurgeons, various ergonomic solutions have been proposed, through the appropriate design of a work environment adapted to the worker, in this case the surgeons, without putting their physical health at risk. A correct ergonomic intervention brings many benefits for the surgeon and also improves the efficiency of the workplace and reduces unnecessary costs, since it is more cost-effective to prevent musculoskeletal disorders in health personnel than to face long-term absenteeism and treatment of these injuries. In this way, the needs of both the surgeon and the entire workforce are met (7,27).

An ergonomic error that can be easily observed in the operating room is the misalignment of the surgeon's hand and his instrument, which can explain the appearance of hand and wrist symptoms (36). Several studies have shown that surgeons may experience decreased contractile strength of the arm after long periods of operation (24). Slack et al (52), conducted a study to determine if the operation has an effect on the surgeon's muscle fatigue, and found that the brachioradialis muscle was the first arm muscle that showed evidence of fatigue with long periods of surgical procedures; in another study whose objective was to identify if the surgery had any effect on the surgeon's basal tremor, they found that the operation led to an increase in hand tremor in all subjects and that this was directly proportional to the time dedicated to the surgery (53). This suggests that prolonged operations without time slots for rest contribute to muscular fatigue.

It has been reported that, when the operating table is too high, surgeons tend to perform inadequate shoulder elevation and internal rotation, which causes fatigue of the deltoid and trapezius muscles. Likewise, placing most of the weight on one-foot leads to additional asymmetric loading, leg and back pain. The forward displacement of the head and the constant flexion of the neck produce tension and pain in the upper torso, which eventually leads to degenerative changes in the cervical spine and shoulder girdle, due to the greater demand on the joints that support the head (when the head is flexed 30 degrees forward with respect to the neutral position, the weight to which the cervical spine is subjected is multiplied by four) (12, 35, 54). Other common ergonomic errors during surgery are fixed postures and leaning the back forward or to one side (36).

Generally, recommendations are based on carrying out technical controls that include structural changes such as bed height and equipment changes, administrative controls such as changes among work personnel to take breaks, and controls on personal protective equipment such as the use of lighter lead aprons or body support equipment (14). More specifically, other suggestions have been proposed that indicate that the height of the table should match the height of the tallest surgeon and that other surgeons should use a stool if necessary, or that the surgeon's hips, back, shoulders, and neck should be aligned (10).

Yu et al (30) conducted a study to measure the effect of stereoscopic video displays in reducing physical risk factors that can lead to fatigue and musculoskeletal injuries during simulated microsurgical procedures. Three hypotheses were examined, one of which posited that these video displays would allow surgeons to adapt to more neutral and less static postures. The results indicated that neck posture was more upright and postural changes were more frequent on video screens than on microscopes; this suggests that video screens may reduce biomechanical loads and muscle strains (30).

Advances in technology have also led to the development of magnifiers and microscopes that could contribute to the reduction of musculoskeletal disorders of the neck and upper limbs in surgeons. Among these technologies is the development of prismatic deflection glasses that have a built-in declination angle, which allows the field of view to be at a fixed angle of 5° below a true horizontal line; these glasses have been shown to significantly reduce neck and shoulder pain in dental professionals by reducing the degree of neck tilt required to adequately view the working field (24, 55). It is therefore recommended to test this tool in work situations, such as microsurgery, that include high visual demands in awkward and static neck postures (55).

Cohen & Gadol (26), outline some of their personal preferences and strategies for maintaining composure and reducing operator burnout during microsurgery. This study suggests that the microscope, which is an essential tool for microsurgical work and movements, should be adjusted to the surgeon's position and not to the position of the eyepieces; it also mentions that the use of an armrest is ideal to obtain a more comfortable and flexible position of the hands, guaranteeing better results in terms of maneuverability and reduction of hand fatigue or tremor due to excessive use of the arm muscles when exercising a stabilizing function (26).

Similarly, it is important that microbreaks are incorporated during surgery to reduce the occupational risk of musculoskeletal injuries and improve performance. Hallbeck et al (56) conducted a multicenter cohort study where they implemented breaks of 1.5 – 2 minutes, with intervals of 20 – 40 minutes during the operative time or when medically convenient. These breaks consisted in the development of exercises focused on rotational movements and activation of muscle groups of the neck, back, hands and lower extremities; several of the surgeons reported improved concentration and physical performance as a result. Park et al (57) investigated the effect of intraoperative targeted stretching microbreaks on surgeons' pain, fatigue, physical function, and mental focus. The results recorded showed an improvement in surgeon's post-procedural pain scores, physical performance and mental focus; 87% of respondents even planned to continue this stretching plan on a regular basis (57).

It is important to mention that the use of these strategies in the surgical setting is limited due to the belief that these breaks can cause distractions and lead to surgical errors. However, several studies have shown that these breaks do not have a negative impact on the surgeon's performance, nor do they cause any distractions, as well as they do not increase the duration of the operation (14, 19). In fact, in a study by Dorion and Darveau (58), it was shown that surgeons who performed microbreaks made seven times fewer errors than those who did not perform breaks.

Key ergonomic recommendations in the operating room

Body posture

Posture is defined as the spatial arrangement adopted by the different parts of the body when they are aligned to perform a specific task such as sitting, standing or running (12, 59). It refers to the relationship that exists between the segmental joints of the body and the muscles that cross these joints to protect the supporting structures and prevent body damage in any position (12). One of the fundamental principles of surgical ergonomics is to maintain an adequate body posture, since in more than 50% of surgeons only poor posture have contributed to the development of their symptoms.

It has been shown that maintaining a position as close as possible to the neutral position of the spine during surgery helps to reduce the strain on the muscles and keep them relaxed, which significantly reduces the occurrence of musculoskeletal symptoms and disorders (60). Therefore, the best way to avoid work-related injuries is to recognize when you have a stable posture and understand the disadvantages of poor posture in the operating room (12). Spinal instability is one of the causes of low back pain, so improving stability decreases mechanical irritation of the spine and reduces symptoms (12).

Rosenblatt et al (61), carried out a study with the purpose of reviewing the elements of an ergonomic operating room environment and the most frequent errors in the surgeon's posture; they described that the three ergonomic errors that occur most commonly in the surgeon's posture are the forward position of the head, incorrect elevation of the shoulder and asymmetry of the pelvic girdle (61). This is why ergonomic measures should be aimed at solving this problem. Since the spine must remain upright to maintain the natural lordotic and kyphotic curves of the vertebrae, it is recommended that the surgeon maintain a neutral body posture. The body should not be shifted sideways, as this can cause muscle tension in the back. The head should be forward **(Figure 2)**. The shoulders should be level and neutral in internal rotation, and the knees and toes should be facing forward (12, 34, 37).

It is recommended, particularly in long-term surgeries, that the surgeon checks his position every 10 to 15 minutes to analyze his alignment and to recognize discomfort and tension. To further protect the torso and lower extremities, the feet should be placed shoulder width apart, the knees should not be locked and weight should not be shifted to the hips (12). It is also important to reduce tension in the hand joints, taking into consideration the intensity with which surgical instruments and materials are held.

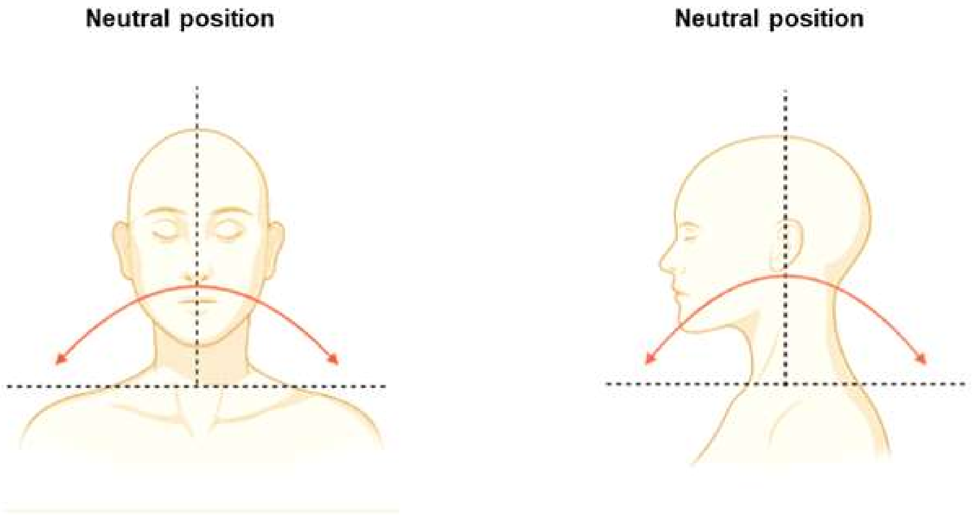

Figure 2**. **Optimal ergonomic position.

The surgeon's head should be upright and it is recommended to avoid tilting the neck forward (flexion) or backward (extension) as much as possible (red arrows). Created with **BioRender**

Surgical equipment and instrumentation

The height of the bed should be raised and adjusted to a comfortable level so that the surgeon can maintain good posture, rather than leaning forward over the patient (60).

It should be checked that both pedals are at the same height and if the opportunity arises, remove the feet from the pedals and place them on the floor to avoid muscle tension; this is important because when a pedal is used at different heights from the floor, it causes an asymmetric load on the lower extremity, generating unnecessary shear forces on the pelvis and lower spine (12).

The chair should be at a comfortable height, where the hips and knees are bent at about 90 degrees or slightly less flexed. Weight should be evenly distributed between the thighs and buttocks, and it is suggested that chairs have a backrest to support and relax the back muscles (60). The armrest can provide the surgeon with support and stability.

When implementing the microscope, it is recommended to use both hands tilting the instrument towards the surgeon, which helps to keep the back and neck in a neutral position; the use of ocular extenders is suggested to avoid leaning forward (60). In the same way, when selecting loupes, the magnification required for the procedure to be performed should be taken into account, since the use of higher magnification levels may increase the weight of the device, generating unnecessary loads (24). Other important factors to consider are the working distance of the lens and the proper declination angle of the loupes, to prevent surgeons from adopting postures that may cause neck strain (24).

Postural breaks

It is recommended to take breaks of at least 20 seconds to 1 minute for the surgeon to stretch, move and return to neutral position, in order to give the body and muscles a chance to relax, relieving tension in the torso and extremities (60, 62). Stretching exercises include flexion, extension and lateral rotation of the neck, stretching of the back and hands, foot and heel raises for lower extremity and ankle stretches (57). To mobilize the upper extremity, bilateral or unilateral arm elevations can be performed, allowing full shoulder elevation, external rotation, scapular depression and retraction to reduce tension at this location (12). Squats are also an exercise that eliminates torso pressures, because it engages the lower extremity muscles and recapitulates symmetrical weight bearing and neutral spine position (12). After the pause, it is essential to maintain the "ergonomic concentration" and focus on the position of the body parts such as neck, shoulders and back, in order to have a correct ergonomic posture during the whole surgical procedure.

Future directions

In view of the increasing incidence of musculoskeletal disorders in microsurgeons, the concern of both health personnel and ergonomists has increased. That is why it has been suggested the implementation of several measures dictated by this discipline, with the purpose of decreasing the number of figures due to injuries at work, as well as to avoid the worsening of the symptoms and that these disorders evolve to chronicity; this could cause a situation that affects the quality of life of the surgeons, limiting them to live certain experiences and subjecting them to treatments to correct these problems. All of this can be avoided with proper ergonomics education in the operating room. Unfortunately, many surgeons never receive adequate training or are unaware that ergonomic instructions exist to help prevent these common workplace injuries. Even when they do receive such training, few surgeons incorporate these guidelines in the operating room. It is hoped that, in the proximate future, ergonomics will be implemented in most surgical programs in order to correct errors and avoid unnecessary interventions. This is achieved by implementing instruction from the education of the students to the training of the microsurgery specialist, since when properly instructed, the surgeon is trained to constantly practice all these exercises and thus improve mobility, increase flexibility, maintain proper posture and reduce pain. Likewise, awareness should be spread so that surgeons report in time the injuries they may suffer, in order to treat them early and avoid complications.

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Chapter 10

Technological Advances in Current Neurosurgical Ergonomics

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ABSTRACT

Ergonomics is often the underlooked but essential component of the human working environment. Ergonomic principles are coupled with the biomechanics of the human body to ensure smooth functioning. The poor ergonomic design of a workplace is known to result in adverse health hazards. The specialty of neurosurgery has witnessed monumental technological advancement in the last century, gaining the title of "modern" neurosurgery. Paralleling the developments in neurosurgery, there have been developments in the ergonomics employed in the neurosurgical workspace. This chapter provided an outline and overview of ergonomic principles related to neurosurgery and ergonomics in neurosurgical devices, focusing on operating microscopes, endoscopes, exoscopes, and other visualization devices. Discussion on ergonomics of instrument designs and advancement in augmented and virtual reality is provided in chapter 29.

1. Introduction

Neurosurgery is one of the most technologically heavy fields in medicine. The dependence on technology and medical devices can be predicted from how rudimentary and gross we were in the diagnosis and treatment of various neurosurgical diseases 40 years back. The Discovery of Computed Tomography （CT） by British Engineer Sir Godfrey Hounsfield and his colleague Dr. Allan Cormack in 1972 at EMI Laboratories has changed medicine and neurosurgery the most.[1] In just 40 years after the adaptation of CT, neurosurgeons all over the world were doing and publishing about complex neurosurgical procedures from skull base to thalamic lesions. The list of diseases and tumor which were previously deemed untreatable become shorter and shorter. With the advent of operating microscope and pioneers in the field like Mahumut Gazi Yasargil, neurosurgeons worldwide become more and more proficient in working on the tumor under a microscope. Endoscopy in neurosurgery has made procedures and locations like the posterior third ventricle easy to access, avoiding many destructive procedures.

The advent of technology has made the patient outcome a predicted outcome rather than a chance. The curiosity of neurosurgeons to improve patient care and development has dramatically advanced neurosurgery in the last century. According to one article on quantitative assessment of technological advancement between 1960 and 2010 found 11,672 patents and 208,203 publications with major thrust areas identified as image guidance devices, clinical neurophysiology devices, neuromodulation devices, operating microscopes, and endoscopes.[2] Ergonomics in the use of these devices is often an underlooked and under-discussed area. A survey of neurosurgeons in three major neurosurgical societies found that 87.9% of respondents experienced work-related musculoskeletal disorder affecting the shoulder, neck, and back, and 84.8% agreed that ergonomics is an underexposed area in neurosurgery.[3] Other studies reported similar results and highlighted that ergonomic furnishing of surgical instruments and operative theatre is essential to reduce the work-related musculoskeletal disorders among neurosurgeons.[4, 5] It will not be incorrect to state that maximum efficiency and safety can be achieved when ergonomics are addressed appropriately with the advancement of technology.[6,7]

2. Technological advancements in ergonomics as related to neurosurgery

Ergonomics is often an under-discussed topic that has led to many changes and paved the path for technological advancement in neurosurgery. There are many examples where different technologies are combined to overcome ergonomic disadvantages. In addition, several approaches are devised for other brain regions' pathologies as each system has ergonomic limitations of its own.[8] With the advancement in technology and increased use of computer-assisted imaging and neurosurgical procedures, simultaneous advances in ergonomics of various neurosurgical instruments are needed. This chapter will try to give an overview of different ergonomics challenges in technological advancements in neurosurgery. It will be an overview of the challenges and issues rather than a comprehensive guide. Discussion of ergonomic aspects specific to neurosurgical instruments is beyond the scope of this chapter.

2.1 Cranial Neurosurgery

2.1.1 Operating microscope

Microscopes became standard neurosurgical equipment in the operating theatre and gained more popularity with technological advances in optical imaging and visualization. However, they have limitations due to the small lens eyepiece, making the surgeon assume posture with poor ergonomics for a prolonged duration. The situation is not much better for the assistant as the resolution in the assistant eyepiece lens is different, and these problems get compounded while looking at depths and difficult angles in various neurosurgical procedures. As a result, there is an increased incidence of neck problems, musculoskeletal disorders, eye fatigue, and excessive tension in the body for the surgeons.[3] Over the years, the size and weight of microscopes had increased, which adds to the ergonomics burden, limits its movements in the operation theatre, and occupies more space. Factors related to physical fatigue must be minimized to reduce the associated tremors and increase safety in neurosurgical procedures.[6, 7] Handling the handle of the microscope for frequent repositioning is a fatigue-inducing factor. The ergonomics-based positioning of handles of microscope aims at better surgeon's grip and arm rotation to move the microscope in a lateral and medial direction. When the wrist is in less ulnar deviation, neutral position and tension, and pull of finger flexors are in balance.[9] Shimizu et al.[10] demonstrated the muscle physiology and utility of ergonomic positioning to handle microscopes. While holding the handle of the microscope with the wrist in less ulnar deviation and arm at abduction, there is less risk for wrist tenosynovitis and shoulder, neck, and back problems.[10] The fatigue experienced by neurosurgeons with the use of microscopes is also influenced by the ocular-corpus length, which is the predominant part of the lever arm of the microscope.[11] This is because the ocular-corpus size determines the length of the load arm, and the insertion point of muscles determines the effort arm. Working with outstretched hands increases physical fatigue, which is reduced by flexion at the elbow joint.[12]

2.1.2 Endoscope

Endoscopes emerged to provide better magnification and resolution at depths as compared to microscopes. However, the major limitation with using endoscopes was limited working space for neurosurgical instruments as endoscope occupies a significant portion of the surgical field. It has been reported that minimally invasive procedures, including endoscopic brain surgeries, put more strain on the surgeon than open surgeries. In studies, as much as 80% of surgeons have reported discomfort during endoscopic procedures leading to lower satisfaction and higher burnout rate.[13-17] This is because of the unique positioning required, with specific monitors and instruments. What is stressing is that 58% of surgeons are not aware or only slightly aware of the ergonomic issues in endoscopic cranial surgeries.[14] Important factors that can improve the ergonomics of endoscopic surgeries include the monitor's position, foot pedals, the height of the operating table, and instrument design. It has been found that most ergonomic monitor position provides a line of sight at 15 degrees downward at a viewing distance of 80–120 cm.[18] Foot pedals for the use of microdebriders, cautery and drills offer an ergonomic advantage in the endoscopic cranial surgeries. However, continued dorsiflexion can be stressful for the tibialis anterior. Endoscopic instruments have less surface area for grasping and less mechanical advantage than conventional instruments for open surgeries. As a result, there is less tactile feedback, control over the devices, and enhanced hand tremors.[19] These limitations are addressed by technological advances to improve ergonomics. Smart arm holder iARMs and EXPERT has their state of functions of free, hold and wait to provide comfort to the surgeon's arm and reduce tremors.[20,21]

2.1.3 Exoscope

The ergonomic constraints of binocular microscopes led to the development of exoscopes which provided open surgical fields, high-definition images, and visualization of complex angles and trajectories.[22] An exoscope is a visualization device installed outside the surgical area. Optical technological advancement has upgraded exoscopes from poor resolution endoscopic devices to current with the ability to record and display 3D high-resolution video of the operative field. Yoon et al.[23] reported in a survey questionnaire superiority of 3D exoscopes in ergonomics, instrument handling, and space availability in operation theatre compared with the operating microscope. They further reported less eye fatigue, no eye stress with 3D glasses, and body fatigue in the lengthy neurosurgical procedure, though with low resolution than the operating microscopes.[23] Ergonomical superiority was reported in a systematic review comprising twenty-nine studies on technical and surgical aspects of exoscopes, and operating microscopes were reported in a systematic review.[24] Holding arm was found to be a significant limiting factor with exoscopes as it needs to be held continuously for repositioning. This situation improved with the use of a foot pedal controller. Several studies have reported prolonged uncomfortable positions primarily for the assistant surgeon using an operating microscope.[25-28] Other studies have reported more comfortable surgical posture and freedom of movement with the use of exoscopes.[22,25-27,29-32]

2.2 Spinal Neurosurgery

Neurosurgeons performing spine surgeries have abnormal back and neck flexion for a prolonged duration. A systematic review found 62% of spine

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surgeons with back pain, 31% with herniated lumbar discs, and 23% requiring surgery.[5] With the technological advancement of exoscopes, ergonomics are reportedly better in spine surgeries with less back pain and work-related musculoskeletal disorders.[33] Ergonomics provided by the use of robotics in minimally invasive spinal surgery decreased both mental and physical fatigue.[34, 35] Robotic-assisted endoscopic laminectomies have been reported to be beneficial in ergonomics in minimally invasive spine surgeries.[35] Robotics and neuronavigation improves the ergonomics of spine surgeons with less reported back pain and other issues.[36]

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Chapter 11

Robotic Neurosurgery & Ergonomics of a Neurosurgeon

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ABSTRACT

The technology of neurosurgical robots is new but very promising. It is under rapid development, and its importance was especially highlighted during the pandemic. It can potentially assist and address any neurosurgical technical nuance, one very important yet overlooked issue of neurosurgery is ergonomics. Many neurosurgeons are not much aware of their ergonomic issues while suffering from various work-related manifestations. It is prudent to discuss the most important neurosurgical ergonomic issues to find solutions to all of them. With the addition of robots, another branch of neurosurgical ergonomics is needed to consider. Since robots are designed to improve ergonomics, they usually have more positive and less adverse effects on neurosurgical ergonomics. However, all the relevant issues of neurosurgical robots and neurosurgical ergonomics need to be addressed. This will help in the further design of both the operating theatres and the robots.

Introduction

“Ergonomics” is a word derived from the two Greek words “ergon” that means “labor/work” and “nomia” that refers to “arrangement”. Combining these two words lead to “ergonomics” that beautifully refers to “arrangement of the working environment”. With the advent of development and understanding and in keeping with the wellbeing of the workers, this concept refers to designing a comfortable working environment for the workers instead of forcing the worker to adapt him/herself to a given or pre structured working environment. This concept addresses the wellbeing of the worker and promotes healthy working environment that “fits” and “designed for the worker's comforts”. This is of utmost importance as it leads to enhanced performance and prolonged productive years on the part of the worker. The optimization of a surgeon's physical environment that leads to his/her enhanced performance is referred to as surgical ergonomics.[1] Ergonomics is simply a scientific discipline that studies the interactions of humans with other elements of a given system.

It entails the application of principles, theory, method and data to allow an optimum design for improved human well-being as well as enhanced efficiency of the system. With the advent of neurosurgery, there have been newer procedures and branches with use of adjuncts that has made many surgical procedures possible yet at the expense of comfort of the surgeon. Probably it is an overlooked domain by most of the neurosurgeons. It is also confused with surgical theatre design only without considering the other important factors that are of extreme value. Unfortunately, many neurosurgeons are also unaware of ergonomics.

There are certain under-rated issues that needs ergonomic considerations. One extremely important issue is of work-related musculoskeletal disorders (WMSDs) which is a growing concern for neurosurgeons as these disorders have a deep impact on their quality of life, working and the length of career.[2] As per the WHO the work related musculoskeletal disorders are defined as all health problems of the apparatus of locomotion (bony skeleton, tendons, ligaments , cartilage, muscles, and nerves) as well as all relevant conditions of ill health that might range from mild or transitory disorders to disabling and irreversible injuries [3]

Neurosurgery has special issues related with the use of microscope, specific positions and prolonged operative times. Neurosurgery requires high level of hand-eye coordination. Moreover, a neurosurgeon has to focus on dark and deep corridors inside the brain. To add on all this muscular strain, there is an eye strain because of microscope use. Then there is heavy machinery in neurosurgery operation theatres that restrict free movements. Every member of the neurosurgical operative team needs to maintain a specific operative position to prevent any inadvertent movement and disturbance in the operative field. This slowly leads to wear and tear in all the muscles that maintain posture, eventually causing backache and neck pain issues. The Musculo-ligamentous apparatus of hand is similarly involved and causes hand fatigue. Then comes the eye strain issues.

With the advent of technology and introduction of latest machinery in the operating theatres, the basic principles of operating room safety and ergonomics need revision.

The Factors to Consider in Neursosurgical Ergonomics

The following factors should be considered in ergonomics in general for neurosurgery. In the coming sections we will consider how robotics can have a positive ergonomic profile in many procedures. it should be performed under conditions that allow:

1. A comfortable environment for all the surgical personnel
2. A safe environment for the patient
3. Proper positioning of the operation table allowing a surgeon to approach the patient and operate in a comfortable position with hands and axial Musculo-skeletal apparatus perfectly aligned.
4. Proper lighting
5. Proper measures against surgical smoke
6. An appropriate length of a single stretch of surgical procedures to allow rest to the stretched muscles. Some procedures are too long and require high level of skill from a single surgeon who can provide the precise results. This level of skill requires longer training duration and experience. In order to address this complicated issue, assistance from a device or other surgeon who can efficiently perform the procedure under supervision of the senior surgeon without compromising quality of work is required. A properly designed robot can assist such procedures allowing supervised assistance while the surgeon takes some rest and relax his muscles.
7. A proper comfortable support to assist the muscles in maintaining posture and allowing movement. It is prudent to provide a proper Surgeon's chair for surgeons that can assist in sitting, allowing long duration of postural maintenance with support to the muscles that would unload the muscles. These chairs have to be automated and equipped with smart technology and sensors to adjust to different postures while the surgeon is at work. Robotic chairs can be one solution.
8. Microscope is the key equipment of neurosurgery. A neurosurgeon needs to work under microscope for long durations maintaining a certain posture. It requires high level of hand-eye coordination. Working with a microscope leads to eye strain which is again a point of concern when considering ergonomics. Replacement of microscope with an exoscope that provides better visualization with lesser eye strain. Robotic exoscope are certainly a breakthrough and will help in the

neurosurgical ergonomics.

9. Precise assistance such as robotic assistance in time consuming intricate tasks that can be done by a robot and a surgeon can easily supervise them with his/her experience.
10. Radiation Hazard is an extremely important point especially in spinal surgeries. The operating personnel need to stand under radiation for long durations. Spinal instrumentation needs to be performed under fluoroscopic guidance. With the advent of robotics, there are several robots available that can precisely perform instrumentation and are extremely useful in this regard. This assistance is of utmost importance as it can spare a surgeon from much radiation exposure. Surgeons can monitor and supervise from glass wall rooms. This is another an important point is neurosurgical ergonomics.
11. Instrument holders can provide relief to many assistants and are again a good point to consider in ergonomics. Holding several instruments is usually a tiring task and does not require skill. It is not a fruitful task for the assistant as well. It is rather an unnecessary work for the surgeons that brings nothing but tiredness and muscle fatigue. Many assistants lose their learning chances and waste their time in doing so. As you maintain the instrument in a certain position, you are also unable to watch the surgical procedure. This point is of utmost importance to the junior neurosurgeons who are in the learning phase. It should be kept in mind that junior neurosurgeons are also more prone to work related muscular complaints. An automated robotic device can easily replace this cumbersome task.

All the above-mentioned salient points make ergonomics a consideration of utmost importance in neurosurgery.

Robotic Neurosurgery and Ergonomics

Robotic neurosurgery is not a new topic. This field has been developing rapidly since the first introduction of robotics assistance in surgery in 1985.[3]

A positive collaboration between robots and surgeons can unveil countless opportunities both for the surgeons and the patients alike. With a surgeon supervising and guiding all the way, there can be tremendously improved results in the form of improved surgical outcomes, enhanced surgical capabilities and ultimately a positive impact on patients.[4]

A relatively slower progress in robotic neurosurgery is because the inherent complexity of neurosurgical procedures that renders robotic neurosurgery an extremely demanding area. The learning curve of neurosurgery is already long, with an even longer curve for minimally invasive surgery and an innovative approach can be designed only once one has been well versed with the conventional skills.

With robotics celebrating 3rd decade of their introduction and a whooping 100,000 surgical assistance and proven benefit in ergonomics and precision, robotic neurosurgery needs more evaluation in advanced fields such as neurosurgery. Robotic surgery is evolving and redefining surgical procedures. Every procedure and every surgical specialty are getting transformed. The younger generation with inherent interest in new technology and digital assistance, brings hope to a rapid acceptance of robotic use in neurosurgery in the coming years.

As the field continues to evolve, it is crucial that surgeons view advancements as enhancing their own capabilities and expertise. Robotics are transforming traditional operating rooms. With an ongoing pandemic, the need of robotic assistance has greatly been emphasized.

The several factors that hinder the application of this potentially beneficial assistance include economic issues, learning curve and lack of research.

The advent of the robotic neurosurgery opens a new chapter of neurosurgical ergonomics related with robotic machinery. The points to consider in robotic ergonomics include:

1. Workstation design
2. Robotic arms
3. Movement of the robot
4. Proper control of the robots
5. Size appropriate to prevent any restriction in movement

Physical Symptoms in Neurosurgeons Attributable to Ergonomical Consideration

To evaluate work-related musculoskeletal disorders in neurosurgeons related with work, the members of the Congress of Neurological Surgeons performed an online survey .This survey considered the following 4 points:

1) The neurosurgeon's experience of work-related musculoskeletal disorders
2) demographics,
3) working conditions,
4) ergonomic features

Their study concluded that the length of procedure is directly related with the occurrence of work-related musculoskeletal disorders. They also evaluated that those surgeons who had ergonomically furnished operation theatres had lesser incidence of work-related musculoskeletal disorders. All those surgeons who were working under better ergonomic conditions had lower incidence of work-related musculoskeletal disorders and thus they were more productive because of better fitness profile and work potential. 90.7% neurosurgeons complained that ergonomics is underrated in neurosurgery. The CNS members concluded that to get the best from the neurosurgeons and as attempt to protect the health and fitness of the surgeons, it is prudent to teach and implement the rules of ergonomics.[5]

Work-Related Skeletomuscular Disorders/Repetitive Strain Injuries and Robotics

Since by implying robotics, neurosurgeons can shorten their length of operative time in one single stretch, robotics can prove themselves to be an aid in making lengthy procedures ergonomically better.

Eye Strain

The operating surgeons do suffer from eye strain because of prolonged focused work especially through the microscope. This is of special significance to the surgeons suffering from refractory errors.

Mental Stress

Another overlooked yet an important point to discuss is the mental stress related with work and performance. Longer operating times, workload and stress to have the best outcomes, sinister diagnoses, emergency surgeries combined with a stressful surgical unit environment add up making neurosurgeons “blown away”.

The Important Factors of Neurosurgical Ergonomics & The Role of Robotic Assistance

There are a few points that should be taken into account while discussing neurosurgical ergonomics. We will discuss the points so that we can later relate them with robotic neurosurgery. This is important in order to have clear concept to design and evaluate the efficiency of robotic neurosurgery. This will provide a guide for the future design and implementation of robotics in the operating rooms. The most common considerations in ergonomics related with neurosurgery are as follows

Length of Procedure, The Standing Time, Position of Surgeon and the Outstretched Intricate Hand Movements

A surgeon needs optimum conditions to keep performing their best in a fatigue free environment. A survey reported 78 % of neurosurgeons suffer pain after a day of surgery and 83 % of these are musculoskeletal pain.[5] Professor Richard Kerr from Oxford university well explained the use of robotics in neurosurgery by stating "This is a very sophisticated tool, where the surgeon is in an ergonomically-comfortable position. It's a very precise instrument and therefore eliminates any sort of human frailty like tremor or fatigue.[6]

The way robotic assistance can play a positive role here by providing assistance in performing some automated tasks e.g. suturing. A surgeon may relax while supervising the robot. In this way, robotic assistance might help to cast a positive impact on surgical procedures.

Position of Surgeons coupled with prolonged duration of procedures

Specific positions of surgeons such as during posterior fossa and cervical surgeries from posterior approach, put the head, neck and arm muscles in a state of prolonged strain. These procedures are also of longer duration. Holding the muscles in this state of extreme strain for a protracted duration of time leads to musculoskeletal pain in the involved musculature.

Preferable Angles

Van't Hullenaar et al studied da Vinci robotic assistance in laparoscopic surgery. The calculated angles for the surgeons. The optimal joint angles were calculated using Rapid Upper Limb Assessment (RULA) tool .Representation of the angles calculated from the sagittal plane photographs: ΔT (trunk), ΔN (neck), ΔS (shoulder), ΔE (elbow), ΔH (hip), and ΔK (knee).The lowest RULA score (most optimal ergonomic position) indicate the ideal ergonomic position for joint angles to fall within the given ranges: ΔT=0–10°, ΔN=0–10°, ΔS=0–20°, and ΔE=60–100°. The angles ΔK and ΔH were defined to be optimal between 90° and 110° and between 90° and 100°, respectively.[7] While da Vinci robotic arms are not widely used for neurosurgical procedures, because of scarce data on robotics in neurosurgery, this study on laparoscopy is important to consider while evaluating robotic ergonomics in neurosurgery.

Ergonomics with Robotic Assistance

Robotic assistance can help a surgeon to perform certain procedures by putting the robot into action while supervising it from a distance. This would allow a surgeon to take rest and have break letting the muscles relax while the procedure is still underway. Several spinal robots are designed to perform fusion procedures and they can successfully perform instrumentation. This fact is of utmost importance in providing an ergonomic solution in prolonged surgeries.

The Use of Microscope

Microscope is the main key instrument in neurosurgical procedures. Again, a neurosurgeon needs to “accommodate” to fit the microscope. For a vertical alignment to use the microscope, surgeon's body should be in a perpendicular line, that involves keeping the ear, shoulders and hips in a perfectly vertical alignment Again, a neurosurgeon needs to use microscope for longer duration in the stated specific sitting position with outstretched hands. As quoted before. Professor from the Oxford university [6] has emphasized at the fact that the use of microscope, the keystone of neurosurgery, is amongst the major causes that breach the ergonomics of a neurosurgical procedures. With all muscles contracted and a balance between agonist and antagonist and added antigravity posturing, this slow wear and tear in muscles and tendons leads to muscular disorders later. In microscopic surgery, a neurosurgeon is bound to use nearly every muscle in the body including the delicate extraocular and iridial muscles. The use of iridial muscles in focusing under unusual lighting is a cause of eye fatigue. Eye fatigue especially if one is a myope or a presbyope. With all the stated points, it is understandable that there should be solution to make the microscope ergonomically suitable.

Ergonomics with Robotic Assistance

With the advent of robotic exoscope, we can easily imply much better ergonomic principle in the operation theatre. An exoscope is the best alternative to microscope and provide quality images to help the operating surgeon.

Surgeon's Hand Fatigue

It has been noticed that neurosurgical procedures especially minimally invasive surgeries that involve prolonged holding and use of endoscope are a cause of hand surgeon's hand fatigue that impairs dexterity and in the long run , it can be a risk factor for hand tremors. Junior neurosurgeons especially the ones who are still getting trained are at even higher risk for hand fatigue.In a study conducted by Kuo. Et al, a comparison of hand grip between robot and surgeon was conducted to assess feasibility. For hand dexterity, they used Purdue Pegboard Test（PBT） and for hand grip strength, the applied the Camry Electronic Handgrip Dynamometer. They concluded that robots do have a good grip strength and can be used during complex surgical procedures to aid an operating surgeon.

With the given long curve of neurosurgical skill, it is obvious that for one to be an expert in the field, he needs to spend years in training and like the captain of a ship, they are seasoned at a much later age group. With the added stress of this peculiar intricate muscular work on normal age-related changes, it is not difficult to assess that with every passing year a surgeon needs to put an extra effort for the best performance. This extra effort cost in more wear and tear in the body and many surgeons need to take some time off which is as mentioned before, difficult for an expert.

Role of Robotics

For the protection of a neurosurgeon, the role of robotic surgical assistance should be assessed as many robots can be designed and trained to perform certain tasks that are unnecessary burden for a surgeon. It is noteworthy that robotic systems do utilize tremors filters.

Here it is noteworthy to mention the NeuroArm（University of Calgary, Alberta, Canada） which has the ability to follow and mimic the surgeon's hand movement. This robotic hand technology is promising and would help addressing several ergonomic concerns. This robotic arm has eight degrees of freedom（DOF）.

Robotic Neurosurgery: Ergonomics in Brain Surgery

The Sitting Position of the Neurosurgeon

The long duration of surgery in a sitting position under microscope has been notoriously related with an increased risk of neck and back pain. For every inch the head moves forward, the head, neck and upper back muscles must support an additional weight of extra 10lbs [8] The added use of microscope also effects the ergonomics.

This issue of high importance ergonomically is unavoidable as one has the responsibility of performing surgical procedures. With the advent of robotic assistance, we can now have a hope of getting “surgeon supervised” replacement in those procedures that can be performed by the robots. It will reduce the sitting time of the surgeon since they can split the tasks with the robot which would be able to “execute” the “mindful skill” of the surgeon while allowing rest periods to the surgeon. In this way, robots can improve ergonomics of brain procedures.

Microscope Issues

Brain surgery is mostly performed under microscope. Again, the operator has to maintain an unhealthy posture for long time durations with eyes focused on the target through a microscope. That causes strain to the eye muscles as well as positive visual phenomenon because of the light settings. For a myope or presbyope neurosurgeon, this eye strain can result in various issues including a risk of the retinal detachment. Keeping in view, robotic exoscopes have been developed. The details of these exoscopes are discussed elsewhere in the chapter. Robotic technology such as ZEISS KINEVO 900, allows a hybrid technology that may allow the surgeon a "straight neck" surgery while providing a 4k display on monitors.[9]Such robots also allow "point lock" and with "navigation interface" they help reaching and visualizing deep seated lesions e.g. brainstem. These points have an obvious positive impact on ergonomics.

Instruments

Holding on to the long, heavy instruments can risk work-related muscular complaints. Again, robotic assistance in various forms including robotic arms, robotic instrumental movement and holding can address this issue. There are several robots including ROSA, Aesculap Aeous, SVR3J and da Vinci arms that can be employed for holding instruments and thus can be useful to improve the ergonomics.

Infection Transmission

Another extremely point especially with an ongoing pandemic is infection transmission. This risk can be certainly reduced by reducing patient-personnel exposure. In surgical procedure, there is some "essential operative time" that cannot be reduced. In this given situation, a robotic assistance can be the only hope to reduce that "essential operative time" thus reducing exposure. This point has been discussed in literature, although the data is yet scarce.

While infection transmission has always been an important point of consideration in neurosurgical procedures but the current covid19 pandemic has highlighted it even more. The Covid19 pandemic affected the elective neurosurgical lists. Surgical procedures had to follow priority and triage which led to postponements of many cases. This point was signifying the level of human-to-human contact in surgical environment. In surgical units, this necessity posed a substantial challenge and hindrance to the normal operative procedures. The postponements of surgeries in order to prevent spread of the pathogen resulted in considerable physical, mental and economic consequences both for the patients and the health facilities. This issue motivated the doctors to explore AI and robotic technology to assist and enable themselves to combat the challenge. This technology can be used beyond the operating environment and can be used to protect other health personnel in charge of patient care by providing digitized patient admission, triaging, recording and monitoring of vital signs, sterilization and contamination feedback, blood sampling and food and drug delivery. In the operating theatre, robots can place intravascular lines, intubate the patient and manage the airway. For the surgical procedure itself, the smaller the number of the surgical team, the lesser the risk of contamination. While robot-assisted surgery can reduce contamination risk, contactless remote robotic surgery would be the ideal scenario to prevent pathogen spread as it technically can be conducted with only the presence of the patient in the operating room. This visionary setting would allow continuing surgery during pandemics without risking increased contamination. Modelling studies based on accurate contact tracing in the operating room to compare detailed scenarios in the surgical environment with and without the use of robots would help to estimate the true benefit of robots in containing pathogen spread.

Beyond the pandemic, use of these technologies in surgical environments can provide other benefits to improve safety and efficiency for the patient and to serve rural areas more effectively through remote surgery. Utilization of AI, virtual and augmented reality can help the surgeon to make the procedure safer, for example, by haptic feedback and projection of critical structures within the surgical field. Centralizing the assistive tools provided to the surgeon into a single component, for example, into a surgical glass, can simplify the application to the surgeon.

History shows that technology has advanced surgery more than any other field. Examples include the invention of imaging, the cautery, the microscope and many more. AI, machine learning and robotic technology may well be the next quantum leap.

Robotic Neurosurgery: Ergonomics in Neuroendoscopy

With the advent of endoscopic surgeries, neuroendoscopy is now a routine in most of neurosurgical centres around the world. Endoscopic surgery is being employed both in brain as well as spinal procedures. Surgery for pituitary gland is mostly endoscopic even in the low-middle income countries. Many surgeons do use endoscopic assistance in cerebellopontine angle tumors. CSF diversion is widely performed using endoscopic third ventriculostomy. For pineal gland tumors, endoscopic procedures are ideal.

Ergonomic Issues with Neuroendoscopy

The importance of Robotic assistance arose after the advent of minimally invasive neurosurgery. The neurosurgeons were concerned that the impediment of implementation of the minimally invasive surgical technique include handling of the instruments and steering through the narrow brain corridors. They considered that a robotic assistance can help them resolving these issues.There are a few issues of special consideration that raise questions regarding ergonomics of neuroendoscopy.

1. Junior Neurosurgeons and Learning Curve= Added time:

   Endoscopy has a long learning curve and because it is a relatively newer field in many parts of the world, most operators are comparatively younger and still in the learning phase. This leads to a prolonged duration of procedure, improper posturing and increased radiation risk in addition to all others as many junior neurosurgeons take fluoroscopic aids in endoscopic surgeries as well.

   Role of Robotics:

   Robotics can help both in performing as well as learning neuroendoscpy.

2. Posture:

   Endoscopic surgery requires maintenance of certain postures against gravity as most of the procedures are under standing position.

   Role of Robots:

   By employing robots, such as Evolution 1 precision robot （Universal Robot Systems, Schwerin, Germany）, the surgeon can have a better control over the procedure while taking some necessary rests and revising ergonomics for his posture and comfort.

3. Holding of Instruments:

   Endoscopic camera holding is as such a task for a neurosurgeon. A neurosurgeon needs to stand holding a camera in a fixed position for prolonged time periods. Robots might help facilitating bimanual manipulations by holding and handling the endoscope and allowing the surgeon to manipulate with both of their hands. Concentric tube robots can provide necessary dexterity without endoscope tilting, while passing through existing ports in the endoscope and carrying surgical tools in their inner lumen.

   Role of Robotics:

   As mentioned above in relevant section, several robots are capable of holding instruments, therefore improving ergonomics

4. Accessibility to Deep Corridors of Brain:

   An access to deep and dark corridors of brain requires expert and cautious steering of the endoscope. Not only it is a stressful and tiring maneuver, the angles required can be hard to achieve with long handled instruments and human hands.

   Role of Robotics

There are suggestions of certain robotic designs that might help in achieving targets. This related to neurosurgeon's ergonomics again. Several robotic devices have been designed to assist steering and navigation in the deep and dark brain corridors, thus assisting surgeons and improving the outcomes and of course ergonomics.

5. Hand-Eye Co-ordination:

Again, while talking about ergonomics, we need to take into account the physical, mental and visual exhaustion of neurosurgeons that might bring him to a breaking point in longer practice. All the points combined; we need to reconsider ergonomics of endoscopic procedures which is now the essential part of neurosurgery. Most pituitary procedures are performed endoscopically. It is now well integrated in neurosurgery and we need to consider every aspect of endoscopy to perfect its ergonomics.

Role of Robotics:

By assisting in holding, steering and navigating the instruments inside the cranium, robotics have a potential to improve the hand-eye co-ordination, unloading the access stress and ultimately improving the ergonomics.

6. Perfect Triangulation Involving Extreme Eye and Hand Muscle Strain :

The basic principle of positioning of surgical instruments based on initial positions of the instruments with respect to a given point to make an imaginary triangle making the points meet is referred to as triangulation. This involves mental concentration and extreme hand-eye coordination. Acquisition and maintenance of perfect triangulation involves holding up difficult and unnatural postures for long duration of time in which the muscles and tendons are not accustomed to. It leads to muscle strain and wear and tear. Another worrisome matter in endoscopic procedure is the loss of triangulation because of the use of tube-shaft instruments working through a single keyhole in a limited operative working space. This result in the psychological tension as well as physical strain, thus contributing to a negative impact on the ergonomic aspect of the neurosurgical procedures. Here the robotic assistance can help in correcting ergonomics by holding the instruments, steering deeper corridors, aid in hand eye coordination and navigation.

Role of Robotics

Concentric tube robots can provide necessary dexterity without endoscope tilting, while passing through existing ports in the endoscope and carrying surgical tools in their inner lumen. [9]

7. *Technical Nuances*

Instrumentation and performance of certain actions may be difficult under endoscope .

Role of Robotics:

Robotic articulations may help in that case e.g. suturing

8. *Remotely Controlled Surgery away From The Site*:

   The provision of operating remotely by an expert neurosurgeon makes robotics an attractive field for performing even those surgeries requiring higher level of training in areas where expert skilled neurosurgeons are not available

   Role of Robotics:

   Being a supervised device, robotics hold potential to be controlled remotely by a surgeon thus allowing rest to a surgeon while he can still offer his skill via robot and also a provision of specialist care at far flung areas where advanced level of surgery and senior level consultants are not available.

9. *Decreasing Extra Burden of Work*

   Robots are believed to perform the rather time consuming work where the manual skill of a neurosurgeon may not be as necessary as during the more intricate work e.g. skin incision, bone drilling, suturing etc.

10. *Special Reference to COVID-19 Pandemic*

    The authors believe that the use of robotics should be seriously evaluated during the pandemic where the transmission of SARS-CoV-2 is high and even after the pandemic is over, we may still face such a risk. The role of robotics has already been discussed in this regard.

Robotic Neurosurgery: Ergonomics in Spinal Surgery

Spine surgery was mentioned most often as the procedure most likely to cause WMSD (Work Related Skeletomuscular Disorder). The prevalence of neck and back pain in spine surgeons is quite high. The reason of this high prevalence of WMSD among Spine neurosurgeons is by maintaining sustained non-neutral positions for prolonged time durations .In spinal surgeons , the posture includes neck flexion for prolonged periods with coronal misalignment while operating in a standing position, frequently leaning over the operating table [9] The incidence of neck and shoulder pain has been reported to approach 40% among spinal surgeons.[10]. Ponnusamy et al. conducted a study on a porcine model using the da Vinci Surgical Robot assisting posterior spinal approaches including laminotomy, laminectomy, and dural closure. This study showed the ergonomics provided by the robots decreased both mental and physical fatigue enabling the surgeon to operate for much longer time durations experiencing lesser fatigue. [11] the Da Vinci system has an ergonomically designed workstation comprising of 4 robotic arms that allow 7 degrees of freedom, enabling a limitless range of motion of the surgeon's wrist. Moreover, it allows 10× magnification as well as tremor filtering. Its scalar motion converts larger hand movements into finer instrumental movement. The binocular vision and 3D display help in perception of depth and ergonomically it reduces eye fatigue and strain. [12] We can now discuss the relevant points

1. Posture:

   Again, spinal surgeries require specific positioning and posturing of surgeons. This, combined with instrumentation procedures, makes spinal surgery among the most afflicted surgical specialty being affected with work-related muscular disorders

   Role of Robotics:

   As mentioned in relevant sections, the noteworthy point is, spinal robots are even better developed e.g. ROSA and Mazor robots and are well trained to perform several procedures such as instrumentation. A surgeon can enjoy the luxury of supervising and operating via robot that is a positive point in ergonomics

2. Radiation

   Spinal surgeons need to perform procedures under fluoroscopic guidance thus they are exposed to prolonged radiation exposure. This adds to immediate and delayed radiation exposure related complications that may range from eye irritation and dermatological manifestations to potentially oncogenic mutations. Again, this is unavoidable as the surgeon needs to perform this procedure.

   Role of Robotics

   Some notable robots such as Mazor robots are capable of performing instrumentations and thus can be allowed to assist in these procedures.

3. Duration

   Longer duration of operation puts strain on muscles as we have discussed before. There are certain spinal surgeries that so far has not found any robotic solution which includes spinal tumor surgeries and scoliosis surgeries.

   Role of Robotics:

   By assisting and performing several tasks, robotics can shorten the operative time for surgeon even if they cannot shorten the procedure time in general. This allows many positive ergonomic changes including rest, relaxation, mental destressing, reduced radiation exposure and reduced human-human exposure that would prevent infection transmission

4. Precision

   Spinal instrumentations require high level of precision. This level of precision requires years of training and experience. Per-operatively it requires prolonged instrumentation under fluoroscopic guidance.

Role of Robotics:

Robotic assistance can address all these issues and thus can improve the ergonomics making it a wonderful working environment for spinal surgeons to learn and operate

5. Instrumentation

   As mentioned above, holding and using heavy instruments may lead to hand muscle complaints during spinal instrumentation.

   Role of Robotics

   The role of robotics has already been discussed in this regard

6. Health personnel

   With robotic assistance, you can limit the number of health personnel as well as divide the staff into shifts allowing rest and decreased exposure

7. Infection transmission

   As mentioned above

Ergonomics of Robots, The Good & The Bad

As we have discussed the salient ergonomics aspects of neuro-spinal surgery, we can now have a look at how robotics can have the positive impact on neurosurgical ergonomics. Robots do provide the potential privilege of offering Automated Procedures under surgeon's supervision. If we just exploit this luxury, we can address several factors of ergonomic importance. First of all, it would allow unloading a surgeon from several "unnecessary tasks" that can actually be done by a machine. This will not only lead to physical comfort and prevention of long term work-related skeletomuscular disorders, but would also prevent mental stress, radiation hazard, infection transmission and better workplace coordination. All of these points are of utmost importance in neurosurgical ergonomics. We have thoroughly discussed ergonomics in general and then specifically with each branch of neurosurgery to highlight the importance of robotic assistance and help in improving ergonomics. Perhaps before the pandemic, this field was overlooked as everyone was busy in following a routine that would discourage the possibility of making a change.

This disruption in routine and some break from strenuous work caused by the sudden onset of pandemic led the neurosurgeons to browsing of options including robotic surgery to optimize and make it possible to adjust in the changed circumstances. Not only it addressed the infection transmission risk, but it also showed the other ergonomic benefits which the neurosurgeons always needed without realizing.

The Bad

While we have discussed the many ways robotics can potentially affect the ergonomics in a much positive way, on their own, there are still notable ergonomics issues that need to be considered. The data is yet scarce and more research is required. There is one study by Lee.et al that has discussed some ergonomics issues with robotics. 84 participants out of these 516 mentioned that they perform <10 robotic procedures annually. Those were excluded to ensure the results just dictate the experience of some surgeon who fulfills the criteria of experienced surgeon. Among the surgeons who were included in the study, 80.8 % were using a da Vinci system, 14.7 and 4.4 % mentioned da Vinci S and standard, respectively. The chairs which were being used by the participants during robotic surgery had common features including adjustable height (97 %), wheels (94 %), seat rotation (92 %) and back support (80 %). 40 % of participants admitted adjusting their ergonomic settings at the surgeon console at every case, 33 % indicated infrequently,16 % reported quite often while ~10 % surgeons never adjusted the settings. 56.1 % admitted having experienced physical symptoms/discomfort which they considered to be related directly to their practice in robotic surgery. The frequently felt symptoms included discomfort of the fingers (78.4 %) ,neck discomfort (74.6 %) , back stiffness 53% , lower backache (~ 43 %), eye strain (~34 %) and wrist pain(33.1 %) Among the 56.1 % who admitted to have suffered from robotic-surgery related symptoms, 57.5 % considered the symptoms bothering immediately after surgery,36.0 % felt it while operating while 6.4 % experienced persistent symptoms. 36.0 % ignored this work-related manifestation, ~32% considered revising ergonomic settings and about a similar 32.2 % considered taking a temporary break till they recovered.

Why Robots Have Not Been Widely Used:

Majorly because of financial constraints, they are not affordable by most of the facilities. This field is still nascent and will take time before it is being used routinely.

Ergonomics of Robotics:

With the advent of surgical technology, the operating theatres need a revision and redesigning to accommodate the new machines to make the operation theater user-friendly with a consideration for the high-profile ergonomics. Surgical theatres have always been considered to have a surgeon-unfriendly environment and this has become even more hostile with the addition of latest, complex machinery. Bulky machines interfere with the working between the operating surgeon and the patient. While robots do potentially improve ergonomics, still a badly designed working place can have a negative impact instead of a positive one. Thus, it is necessary to implement a proper conceptual ergonomic system design of this complex technology in order to relieve the stress of the health personnel leading to improved efficiency and safety. The importance of ergonomics has bee underscored. Not only for the doctor, but also for the safety of the patient. It has been estimated by the Food and Drug Administration that half of the 1.3 million unintentional patient injuries each year in the US hospitals maybe a result from from poorly designed instruments. This raises questions on how to highlight ergonomics and teach the doctors to make such changes to allow a healthy environment for both the health personnel and the patient.

The advent of the field of robotics should be translated as an extended hand from robots/machines to the human operators. This potentially productive partnership should be designed to emerge as a healthy partnership. This also means that the surgeons will be needing to learn new skills to command and control a machine to perform the work they want it to perform. They will be a master and will have to train a teacher who has special demands as it is not a living object. These potential benefit needs a proper key to unveil the treasure.

Before implementing robots in a theatre, we need to do research and conduct a scientific analysis of machine–human partnership. This should be followed by regular monitoring of this interaction to make it fruitful. This extremely important domain is the subject of ergonomics, [13] The whole plan should be eagerly designed at the early stage product design. In the product design stage, the choice of material and manufacturing method needs scrutiny to obtain maximum positive results.

For example, in literature, it has been mentioned that robots approaching unseen from behind or above caused mortalities. This indicates a relook on the workstation design and safety of the equipment used. Another example of the robotic design, especially the da Vinci arms is the motion of the motile robotic arm. Being a machine, these arms are not as sharply controlled as human's and they are also rigid. To allow safer movement, a proper design, size and control of the arm is required. In their work, Stylopolous et al shared six proposed points for research. These points are as followed:

(1) Establishment of a databank for accident analysis;
(2) field studies of design requirements of robotics workplaces;
(3) perception of the robot arm movement;
(4) function allocation between humans and robots
(5) development of safety sensors.[14][15][16]

For getting the most benefit from the robots, a neurosurgeon needs to keep all the positive and negative points in mind in order to help design the perfect “tailored” machine for his/her own benefit.

During the pandemic, the importance of neurosurgical robots was highlighted and raised the level of interest in this field. It brings hope that the day is not far from now when we will be able to enjoy a much ergonomically better operating room environment.

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Chapter 12

High-Reliability Organization in Neurotrauma and Neuroemergency Services

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ABSTRACT

High–reliability organizations are gaining increasing interest in healthcare, especially in high–risk settings The fundamental basis for a high reliability organization is to have its own set of principles that allow it to focus on the analysis and subsequent resolution of potential emerging problems through the correct use of resources. Neurologic emergencies are frequent and often catastrophic. Every year millions of people suffer severe traumatic brain injuries, severe spinal cord injuries, acute strokes, status epilepticus or subarachnoid hemorrhages that require immediate medical attention. Una evaluación completa de las enfermedades durante situaciones agudas suele implicar un diagnóstico especializado, lo que a menudo se traduce en una nēcesidad de transferir al paciente a centros especializados en su padecimiento. The Development of measures usually requires substantial resources and knowledge to be open to a few health care organizations in the Development of standards and relevant clinical content. Many obstacles to the introduction of neuro emergency treatment care programs need to be addressed. To improve treatments and outcomes, the advancement of technology suitable for the use of neurologically ill patients is essential. When innovating ideas that focus on the development of diagnostic or prognostic capabilities useful in resolving acute neurological emergencies, a technologically developed support system is needed. Here we will discuss these systems for neurotrauma and neurological emergencies. We would also discuss potential differences in current processes and recommendations to strengthen emergency response and solutions to address these inequalities.

Introduction

Neurological crises are normal and frequently crushing. On an ongoing basis, a huge number of individuals fall victim to conditions severe enough to require clinical treatment because of traumatic brain injury, spinal cord injury, acute stroke, status epilepticus, or subarachnoid hemorrhage [1–4]. Because of this, in order to be able to perform a complete and efficient analysis of these diseases in a difficult environment, it is often necessary to have access to advanced diagnostics and therapies by referring the patient to qualified centers. Postponements in finding or potentially treatment may bring about deteriorated results; subsequently, streamlining of diagnostics is basic.

If we keep in mind the general definition of clinical error – "the disappointment of an organized activity to end as expected or the use of an incorrect intention to achieve a point" – we can evidence its usefulness when considering the possibility of patient harm [5]. In order to reduce the number of clinical errors committed during transport, and therefore to keep patients safe, a great effort has been made to promote activities that rely on ideas from the aviation business, such as the use of packaged diaries and mediations, to reduce some discrete types of clinical errors [6,7]. In essence, the meaning of clinical error is more comprehensive as it keeps in mind the extraordinary danger to which patients are subjected when suffering from missed conclusions and imperfect corrective plans, higher-demanding diligence that lies at the heart of concentrated medication consideration.

However, precise findings and successful conveyance of treatments are convoluted by quickly evolving conditions, high vulnerability circumstances, and deficient information – circumstances classically inherent in the critically ill. For this reason we propose that, in order to improve their capabilities, health professionals working in emergency units may have the option of benefiting from those researchers who are dedicated to studying companies that, despite their limited ability to withstand errors, should remain especially superior in rapidly evolving conditions. There are various models to clarify solid and safe execution in high-risk organizations (HROs) [8], the investigation of hierarchical mishaps, flexibility designing [9], and typical mishap hypothesis.

When a crisis care framework develops, the extent of emergency medicine (E.M.) extends. Exceptionally prepared doctors give most emergency department care. A full-grown scholarly expert association can propel the field, which would now be able to support cooperations and subspecialization, public data sets, and companion surveyed diaries. Emergency clinical benefits frameworks are created and run on the city, territorial, and even public levels.

The doctor and the innovation are shipped off the scene in the expectation of giving a prompt undeniable degree of care when generally required. At present, the executive's frameworks are set up for measure improvement, quality affirmation, and cost controls.

Neurosurgical emergencies

Neurosurgical emergencies are divided into some special categories (vascular, spinal, cranial oncologic and trauma) which each include certain different pathologies according to the class to which they belong, for example:

- Vascular, such as malignant cerebral infarction, aneurysmal subarachnoid hemorrhage (aSAH), hemorrhage secondary to arteriovenous malformations (AV), space-occupying intracerebral hematoma, high-grade dural arteriovenous fistulas, unstable aneurysms and other procedures that include revascularization in patients with evidence of disease due to relevant vascular occlusion.
- Cranial oncology, as in the case of brain metastases secondary to any kind of primary tumor, malignant primary brain tumors, benign or low-grade tumors with marked parenchymal compression or progressive neurological deficits, and pituitary tumors with signs of cranial nerve deficits, visual impairment or endocrine deficiency that cannot be treated conservatively and require surgical management.
- Spinal pathologies, including degenerative conditions of the spine with acute onset of motor deficits and vegetative dysfunction, instability and signs of spinal cord compression secondary to spinal metastases or primary tumors that also present severe pain, intraspinal pathologies presenting signs of spinal cord compression, progressive myelopathies of both cervical and thoracic vertebrae, vertebral body fractures with refractory therapy and severe pain and spinal cord instability and compression refractory to treatment.
- Craniocerebral trauma, includes any scenario in which intracranial pressure cannot be controlled by conservative treatment such as chronic subdural hematoma with neurological symptoms, acute craniocerebral trauma with subdural hematoma and epidural hematoma, among others.
- Hydrocephalus is secondary to any condition that produces a gradual increase in intracranial pressure with signs and symptoms suggestive of elevated intracranial pressure or shunt dysfunction.
- Infection or other emergencies, such as benign or malignant peripheral nerve tumors with signs and/or symptoms of neurological deficits and painful syndromes unresponsive to noninvasive therapeutic modalities.

Clinics are High-Risk Associations

The U.S. Institute of Medicine (IOM) 's a fundamental and powerful report on patient security [10] recorded dangers in American emergency clinics. The report assessed the number of deaths each year because of antagonistic occasions that happen in clinics: the study found that the lowest value (corresponding to 44,000) was probably close to being as high as the absolute number of people who were injured in street mishaps (43,598), while it was slightly higher compared to the number of deaths due to some form of lung damage (42,297), which in turn was significantly higher than the number representing the number of deaths due to AIDS (16,516). In correlation, commercial flights did not sustain many fatalities (369). A new systematic survey affirms the broad patient security issues in clinics [11]. In mid-2000, various investigations revealed comparable appraisals all through the world. The broad scope of an event of unfavorable occasions in different experiments may rely upon multiple meanings of unfriendly occasions and on a quality norm of the consideration. In addition, numerous investigations may have been one-sided due to trouble in detailing, a dread of expanded clinical suits, absence of clear definitions and assets, muddled advantages, fault culture, and different angles that regularly portray the clinical associations.

Therefore, a portion of the information announced by studies may really belittle the actual event of unfriendly occasions inside clinics. Regardless, the event of preventable unfriendly circumstances is high: around 10% of patients in clinics experience preventable unfavorable occasions [11]. The situation is even less satisfactory when one looks at that as some examinations show that around half of unfriendly circumstances might have been forestalled [12]. These assessments show that medical clinics are indeed high-risk organizations and therefore their activities should be focused on trying to reduce or even eliminate those antagonistic occasions. In order to achieve this, it is recommended to actively seek countermeasures that make use of effective methodologies in '''business as usual''' dangerous businesses. As a result, clinics are currently considered high-hazard frameworks, where a procedure towards changing them into HROs must be applied. Time slipped by since the real selection of the new procedures has been lacking: notably, authoritative changes need quite a while to show applicable, perceptible impacts. Significantly additional time is required when changes are identified with social perspectives, just like an authoritative change into an HRO. Notwithstanding, it very well may be conceivable that the change of medical clinics into HRO isn't difficult to actualize because ''customary'' HROs are significantly not the same as clinics. Surely, medical clinics have explicit qualities that should be painstakingly thought about.

Foundational Elements of HRO

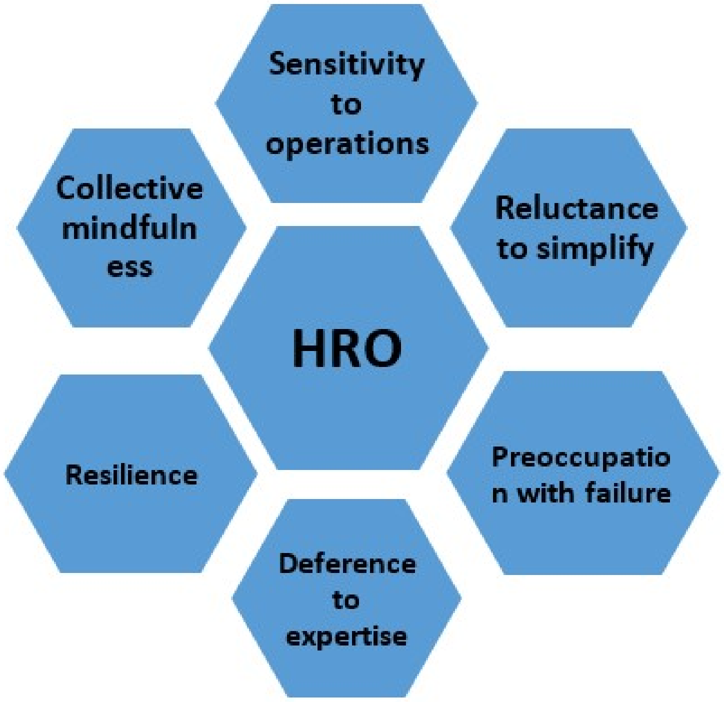

Figure 1: Six foundational elements of HROs

1. **Sensitivity to operations:** HROs work rapidly to recognize oddities, issues in their framework, and likely errors to diminish the number of genuine mistakes.
2. **Reluctance to simplify:** HROs stay away from excessively basic clarifications of failure. This doesn't imply that HROs don't attempt to work on cycles however much as could be expected; rather, they don't ascribe inability to a solitary reason.
3. **Preoccupation with failure:** HROs are centered around foreseeing and taking out disasters instead of responding to them. "Close to misses" are seen as freedoms to improve current frameworks.
4. **Deference to expertise:** HROs develop a culture where colleagues and hierarchical pioneers concede to the most proficient – not the most senior or experienced – individuals apply to the current issue.
5. **Resilience:** HROs give close consideration to their capacity to contain mistakes rapidly and extemporize when challenges happen with the goal that frameworks are robust and can work notwithstanding mishaps.

6. **Collective mindfulness:** Operating carefully and making fundamental changes in a reasonable way to deal with the startling in a problematic, severe environment makes a culture of wellbeing and supports profoundly dependable frameworks. Aggregate care likewise gives a psychological direction that empowers continuous learning and assessment by permitting pioneers at all levels to reliably recognize possible mistakes or dangerous conditions before they present great danger.

Emergency Medical Services

Very few nations have prepared systems against stroke; if we consider Brazil, where a National Stroke Project was implemented, which was vital to improve stroke care in the country, we can observe that the company created intense habitats to prepare the pre-medical clinic staff for any stroke case. The pre-clinic crisis clinical framework was effectively included. In a pilot project in Porto Alegre (Brazil), six strokes were prepared on intense stroke mediations. After the task, the extent of stroke patients treated with intravenous thrombolysis (rt-PA) expanded from 1.7 to 5.3% [13]. On the other hand, the role of applications on cell phones as a strategy to help both patients and their families should be valued to perceive indications and initiate crisis administrations. A few encounters have been accounted for in stroke and are being actualized with acceptable outcomes in South America [50]. Techniques to improve pre-medical clinic care incorporate mindfulness crusades, a concentrated crisis number, crisis clinical benefits preparing in neurological crises, clinical organizations' presence, need moves directly to proper focuses, and cooperation between clinics [14-16]. First of all, it is necessary to organize patients according to the distinctive site where the stroke occurred in order to be more efficient in allocating assets and planning transport times, especially if thrombectomy is affordable. There are scales that can help categorize those patients who have some type of significant vascular risk but, despite their prominent involvement, are not readily identified due to their low specificity [17-20]. There are simple approaches that can be used to apply the preclinical approach to the seizure patient, these incorporate not only decision medications, but also instructions on how to proceed with dosing and the requirements for respective tests such as, for example, refined blood glucose before medication.

For patients with TBI, there are additionally specific rules proposing suggested levels of oxygen immersion, pulse, and the utilization of explicit scales for assessing the degree of awareness, for example, the Glasgow Coma Scale, including the circumstance of the evaluation [22]. A review evaluating the TBI results of 550 patients in nine habitats in South America found that half of the patients who were admitted within three hours of the mishap and most of the patients came directly from the location where the mishap occurred [23].

The transformations important to the preparation of every crisis framework rely upon the country's financial and social truth, the presence of an incorporated pre-emergency clinic clinical benefit, just as on the need to coordinate public and private administrations.

Neurocritical Care

Particular units improve clinical outcomes in patients with severe neurological conditions [24,25]. Factors that may influence improved outcomes include: hemodynamic management with an emphasis on the mind, less continuous use of sedation, access to demanding neurological monitoring, and assessment by experts trained in infection [25,26]. Numerous difficulties should be looked for the legitimate working of these units in spots with not many assets. Bed accessibility, for instance, can be a significant issue. Another test is the absence of formal specializations and partnerships in many nations [27]. There is minimal epidemiological data with respect to the presence of neurological critical care units (NCCUs) and their capacities. A new study addressing the issue in Latin America on the heterogeneous capacity of their for the treatment of subarachnoid discharge showed that only 12.5% of these have medical care specialists with neurological training, where 67% of the units were described using a distributed ruler to coordinate therapy, 25% had no way of accessing the 24 h figured tomography filter, and only 52% came close to checking transcranial Doppler [28].

The improvement of clinical rules adjusted to nearby real factors can especially add to the progression of the construction of neurological crises' treatment pathways, so it is of utmost importance that low-wage nations develop their own examination in intensified neurological treatment, as existing information created from nations with high reliability services may not necessarily be applicable to lower-resource, low-wage settings. Conventions and agendas are tools that can help with observing administrations, especially in settings where the experts practicing in the NCCU have not been formally prepared for neurocritical care. As of late, the NCS has made suggestions on principles of NCCUs, assigning units into levels relying upon capacities to deal with complex patients, which may prove to be particularly valuable in those countries with access to low assets as they may find it a useful guide to structure their own care frameworks and thus provide them with a system to effectively organize their own assets [29].

High-Reliability Organization in Neurocritical care

The investigation of high dependability putting together in essential consideration is as yet in its beginning phases [30,31]. Similarly, given the different environments in which they were conducted, it is difficult to focus, with any given model, on how high the reliability rating must be to be considered basic. Despite that, it is an undeniable fact that ICUs are the kind of high-risk, high-danger environment that benefits from unwavering high quality when resolved: the possibility of error in the ICU is omnipresent and sick people are constantly and particularly defenseless against injury all the time. High uncompromising quality getting sorted out may help forestall the two disappointments in the association of care and disappointments in a specific patient's consideration. Nonetheless, as analysts examine how unwavering high quality getting sorted out can be executed in basic consideration, emphasize that the cycles and practices for instituting key high reliability standards must be adapted to the ICU environment.

Considering how difficult it is for us to accept that, even if people receive excellent consideration and treatment, considerable mortality rates are still maintained; we will take the liberty of making a couple of general comments regarding the way HRO concepts are executed in ICUs. Being reluctant to resign oneself to failure implies moving from an indifferent perspective covered under the pretext of having done no harm on purpose, but doing nothing to avoid it, to looking outward and closely exploring disappointments explicitly to address regions of potential danger with the ultimate goal of preventing future calamities. Adaptability because of sudden occasions and consciousness of framework impacts is signs of patient consideration in the ICU.

To value how HRO standards may be instituted in the ICU, we must weigh the basic question of incapacity of inability to meet the practicality focuses for early objective coordinated treatment of septic stun. All the more explicitly, envision an occurrence wherein a patient with serious sepsis didn't have a temporary situation of a focal venous catheter and evaluation of hemodynamics. Though the regular way to deal with this issue may include standing by to address this issue until a few instances of postponed revival happen and result in at any rate one passing, the HRO approach underlines distraction with disappointment and hesitance to rearrange. An HRO approach implies that this occurrence ought to be examined quickly, regardless of whether the patient had brilliant clinical results. As the case is examined, it should be subjected to meticulous consideration, to deduce the specific events occurring in the ICU that may have caused certain delays; however, doing so not to pardon the deferrals but rather to create tough frameworks that will permit properly fast revival even with such different components. In addition, the survey should be conducted by a team composed of an official multidisciplinary staff that is likely to include both assistants and alternates. The aftereffect of the survey would be a way to improve revival of patients in septic stun, probably through courses that include in their curriculum a set of simulations that serve as progressive training before the onset of the next patient with septic shock.

Time-critical neurological emergencies

- **Acute ischemic stroke**

Acute ischemic stroke influences a huge number of individuals around the world consistently, causing huge morbidity and mortality [32]. The yearly age-changed rate per 100,000 populace is 105–262 in India [33] and 140.1/100,000 in Chile [34], contrasted with 158/100,000 in the US [32]. The above figures may have to do with the restriction of the use of recombinant rt-PA due to its short therapeutic window, which is why, each time, countless patients present out of time. In any event, for the individuals who are dealt with, utilitarian results and the time span between stroke manifestation beginning and medication organization are contrarily [35, 36]. Treatment choices require non-contrast computed tomography (C.T.) to preclude intracranial drain; other stroke copies are normal [37]. While CT innovation is promptly accessible in many urban areas, rustic settings and agricultural nations might not have quick ensured admittance to this symptomatic instrument or the talented work force to decipher the pictures. In any case, it is ironic that when CT is free, valuable time that could be used for timely treatment is often spent on obtaining and understanding the images, causing a delay that would inevitably play an exceptional role in influencing the prognosis. Elective procedures that can aid ongoing symptomatic detachment of ischemia from hemorrhagic strokes are required with insignificant emotional translation. Such epic strategies could speed time to treatment or increment the number of stroke patients who might be qualified for treatment, in this manner improving results. This innovation could serve to separate competitors from far-fetched applicants and help in prioritizing C.T. filters.

Furthermore, diagnostics could be converted into the pre-clinic setting, permitting Emergency Medical Services to emergency patients to the most proper offices—subjects with intracranial discharge could be taken to neurosurgical able offices, while those with ischemic stroke could be taken to the nearest suitable office for the rt-PA organization. Uncoupling the dependence on C.T. to decide treatment could, at some point, permit outside-of-clinic treatment alternatives as many stroke casualties first present to essential consideration doctor workplaces or face delayed emergency vehicle transport times [38]. Pre-emergency clinic frameworks that use doctors could, at some point, regulate rt-PA before emergency clinic appearance if hemorrhagic stroke could be avoided, or ischemic dead tissue authoritatively analyzed, with purpose of-care advancements. The dread of causing intracranial drain is frequently referred to as a motivation behind why thrombolytic treatment isn't offered by treating doctors [39]—progressed age, Length of manifestations, and seriousness of stroke increment the danger of discharge. Hemorrhagic change of ischemic stroke with the utilization of rt-PA stays eccentric in individual situations [40], and treatment reaction and clinical improvement are variable. The outcome is that clinicians can just offer an informed estimate of the opportunity of recuperation or deterioration for singular patients dependent on treatment decisions. A constant, purpose-of-care test that will better foresee the danger of discharge or likelihood of a good reaction to treatment with the normal advantage of diminishing trepidation and danger of intracranial drain is required for these clinical situations. By using this type of study as a method of assessing the proportions of genuine hazard benefits in choosing a particular course of therapy, health care providers could prove helpful, not only to those patients who might otherwise be disadvantaged, but also to their respective family environments.

Non-convulsive status epilepticus

Non-convulsive status epilepticus （NSCE） has the characteristic of being difficult to diagnose clinically and with possibly devastating outcomes if left untreated [41]. This condition shares similarities with convulsive status epilepticus in that non-convulsive seizures whose convulsive duration of movements is related to states of extreme helplessness may also be controlled when treated early [42-44]. NCSE might be available in patients with unexplained unconsciousness or modified mental status; a few patients might have the option to follow orders in spite of epileptic action on EEG [45]. This is of exceptional worry is basically sick patients and may muddle the course of up to half of those in a state of unconsciousness [45,46]. NCSE is predominant in patients with horrible mind injury, subarachnoid drain, hemorrhagic and ischemic stroke, and cerebral threat, where these seizures may add to auxiliary wounds and demolished results [47]. NCSE may copy acute ischemic stroke [48], and such patients are sporadically treated with rt-PA. Separating NCSE from intense stroke would limit such therapies and reduce the rt-PA organization's attending hazards. As of now, the finding of non-convulsive status requires consistent EEG checking, which is for the most part accessible at tertiary reference places. In any event, when accessible, the time needed to put anodes and the assets expected to give talented checking and translation make persistent EEG observing grave in many focuses. Since treatment and recuperation are time-ward and conclusion is troublesome, options in contrast to conventional EEG observing are required. Diagnostic tools with easily decipherable results and a primary focus on care could improve the course of care for many patients.

Traumatic brain injury

Modified mental status after an injury is normal yet doesn't generally address a traumatic brain injury (TBI). A veces, dolencias previas, crisis precursoras relacionadas con la salud o cuadros de intoxicaciones, distorsionan la clínica presentada por el paciente. In Emergency Medical Services, where these patients are usually classified in their assigned trauma slots, it is often the case that the presence or absence of an injury-causing instrument is anything but a solid indicator of a patient's basic injuries [49]. Helicopter transport from an injury scene is regularly mentioned because of doubt of conceivable TBI for patients who eventually don't have huge wounds [49]. Crisis Departments frequently get head C.T.s that at last end up being ordinary, and existing clinical choice standards have not decreased this training in view of expansive consideration rules and a hesitance to miss high grimness wounds [50,51]. Further, typical head C.T.s don't ensure that extreme injury is absent; beginning radiographic discoveries in diffuse axonal and worldwide hypoxic wounds might be average even in a clinically crushed patient. These situations address a hole in the capacity to distinguish neuropathological occasions in the TBI quiet. Advances in terms of the variants to be analyzed can help, not only at the time of the emergency, but also during the transfer and in the therapeutic process of survivors of severe neurological crises. Deferred acknowledgment and treatment of extreme TBI might be destructive. Forceful aviation route, ventilatory, and intracranial pressing factor the executives working together with productive neurosurgical decompression and hematoma departure; can be the turning point that will decide the patient's life or death. On the other hand, endotracheal intubation or osmotic specialists' utilization for intracranial pressing factor control in patients without TBI presents potential damage without the potential for advantage. Upgrades in this patient populace's symptomatic abilities are expected to better emergency assets and separate those most in danger from those not in danger.

- **Meningitis**

The finding of meningitis is usually direct. It depends on the investigation of the cells included in the cerebrospinal fluid samples. The development of innovation would possibly be helpful in shortening the waiting period for testing these samples, but the clinical effect could almost certainly be negligible.

Separation of meningitis etiology—bacterial, viral, contagious, or sterile—without anticipating society results would largely affect clinical consideration [52]. Against irresistible specialists could be custom-made in a catalyst way, steroids could be offered uniquely to those destined to profit, and outpatient the executive's procedures could be created for the consideration of patients at generally safe of helpless results [53]. Guidelines currently recommend treating empirically with broad-spectrum, virus-hostile anti-infective agents for 24 to 48 h while CSF culture results are anticipated; this treatment is just accessible as an inpatient, requiring emergency clinic affirmation for some patients who eventually have non-bacterial, non-HSV meningitis that need indicative help [54]. In created nations, around 4 for every 100,000 people each year create bacterial meningitis, bringing about sizable costs of money-related and clinical assets [53]. Improving new insights into the fundamental clues that could serve to rapidly differentiate and separate one type of aseptic meningitis from another of bacterial etiology, for example, could shorten the vital overemergency suffered by these patients and the overtreatment of patients with suspected meningitis due to ignorance of its cause.

Recent Neurosurgical Tools

There have, as of late, been quick advancements in clinical innovation in crisis offices. Scientists have been chipping away at building up another mind injury identifier that is modest, simple to utilize, and can give almost quick outcomes.

- ***Volumetric Electromagnetic Phase Shift Spectroscopy* (*VEPS*)**

This gadget imparts radio signs that go through the mind and are identified utilizing an extraordinary receiving wire. The main innovation is called "Volumetric Electromagnetic Phase Change Spectroscopy (VEPS)", with which it is possible to identify variations in the characteristics of the tissue coatings of the organism through electromagnetic estimates of multi-frequency and non-contact, as they are performed outside the body along these lines, providing fast and accessible tests [55,56]. This is a symptomatic strategy for mind injury that can be utilized in developing country zones where the populace has no admittance to cutting-edge clinical innovation and administrations [55]. Thus, the patient will get a fast determination, even from nonspecialized faculty, and it would then be able to be concluded whether to move him to cut edge clinical benefits for additional neuromonitoring, which can be essential for the result and the personal satisfaction of the patient. The truth will surface eventually, which of these mechanical arrangements will turn out to be regularly utilized later on to help analyze cerebrum injury, and the

VEPS headset is just finishing little preliminaries right now, so it is still a long way from arriving at the country networks it desires to help. In any case, the improvement in this field shows us about the possible advances that have recently been made in drugs and analysis for catastrophic mental injuries [57, 58].

- ***Infrascanner Model 2000 Intracranial Haematoma Detector***

The Infrascanner Model 2000 Intracranial Hematoma Detector is a new tool that has recently obtained FDA approval and is intended for use by surgeons specializing in nervous system surgery. It is a device intended to serve as a basic screening instrument that is simple to manipulate and capable of being used to identify those at high risk for intracranial hematomas due to their demand for particular therapeutic management, which includes the use of CT as a diagnostic aid [59]. Intracranial hematomas coming about because of an awful mind injury are perilous and have been accounted for to happen as the essential injury in 40% of patients with severe head injury [60–65]. Fruitful treatment regularly depends upon ideal conclusion and mediation before neurological decay. The early distinguishing proof of a mind haematoma can assume a huge part in encouraging transportation of basically harmed patients to offices, confirming Infrascanner's initial conclusion and offering careful mediation. By all accounts, the wilderness for the further administration of a possible patient with hematoma. This device was designed to be used effortlessly by all physicians; being able to quickly determine if a hematoma is available or not. The principal doctor at the location of injury would then be able to choose whether the patient ought to be promptly moved to a high-level clinical focus to be dealt with and checked. Although there is a possibility that positive results may regularly be false, the impact of these errors is actually very small. Ultimately, people who end up being diagnosed with hematoma will go on to be tested promptly, and the intense exchange to a neurosurgical division would be useful for the patient. This gadget utilizes close infrared innovation to distinguish intracranial dying. Extravascular blood assimilates close to infrared light more than intravascular blood because of the higher groupings of hemoglobin in an intense hematoma contrasted with cerebrum tissue.

- ***Clotbust ER***

There is another interesting ultrasound framework: The Clotbust ER who has gotten the C.E. mark, these make possibly a significant instrument for the crisis division. The Clotbust ER is used to convey remedial ultrasound energy noninvasively, with the aim to blocked veins in the cerebrum, accompanied with standard intravenous thrombolytic treatment. The energy of the ultrasound bar is changed into the energy of smooth movement. At low pressing factors, this spilling in the core of the cerebrum creating gentle mixing, prompting extra fibrin locales' openness to plasmin. Incorporated programming controls the conveyance of predictable restorative degrees of energy needed to achieve acoustic streaming; this causes the gadget administrator free, then maintains a strategic distance from the requirement for an accomplished ultrasound expert [66–68]. A few clinical investigations have proposed that when is applied ultrasound energy during customary intravenous tPA thrombolysis, the cycle of cluster lysis is enlarged, permitting a more fast goal of the bloodstream to the ischemic cerebrum. Sonotrombolysis is the tittle that receive this cycle. In the future is expected that IV thrombolysis might be supplanted by the utilization of cavitating microspheres related to sonothrombolysis; which may be ideally to improve clump disintegration further. The circles have a small size (1.2 microns), who can permit these to infiltrate, and later go undergo the blood coagulation's fibrin network [69, 70].

- ***Presto***

Professional Neurosurgeon have another instrument vital for crises is the Presto, this screens cranial bloodstream without a sonographer. With this gadget have gotten FDA freedom, and it permits any doctor to perform cranial bloodstream observing with no necessity of an expert sonographer. The framework highlights exclusive auto locating innovation that allows clients to handily find and keep the ultrasound pillar zeroed in on the cerebral vein [71]. The Presto 1000 Flow Monitor will assist with ICU and careful patients by distinguishing anomalous changes in cerebral bloodstream and alarming the going to nurture, carrying other institutional assets to analyze the reason. These stream irregularities might be markers of extreme conditions, for example, vasospasm from aneurysm cracks or head injury, unsettling influences in mind autoregulation, or MCA blood clumps [72]. Considering its capacity and ease of use, this can be truly considered a crucial gadget for neurosurgical crises. In the absence of the information on a sonographer, even a lesser recorder can quantify cranial bloodstream and rather quickly give critical data to the subject matter expert. This guarantees that proper treatment is quickly given and can have the result of saving the patient's life.

- ***HeadSense***

A fundamental gadget for neurological medical crises is the HeadSense intracranial pressing factor screen. In this gadget, the earbuds may help try not to need to bore into the cranium. Raised transcranial pressure from a physical issue or sickness is a hazardous physical state that can be perilous, excruciating, and weakening. Since our empty heads don't permit conventional outer pressing factor checking, obtrusive strategies that enter the skull have been utilized. This is the reason intracranial compel observing keeps on being established in the twentieth century. With straightforward earbuds, even a inexpert junior doctor can undoubtedly choose whether the patient's intracranial pressing factor needs moderate or careful treatment. This choice can be critical for the patient's life, just as for the board's monetary wellbeing. A Bluetooth-empowered tablet gets the HeadSense gadget's information and examinations it to give the last yield of the pressing factor [73]. This is a battery-fueled tomograph and can be moved to the patient from space to room, permitting it to be utilized in spots, for example, the facility, the ICU, and the crisis division.

- ***Bodom***

The most recent improvement within NeuroLogica's convenient processed tomography imaging line is the Body/Tom. The battery fueled BodyTom might be shipped out of space to room and is viable with PACS, careful route, electronic clinical records, and arranging frameworks. Its extraordinary abilities give top-notch C.T. pictures any place required, including the Clinic, ICU, activity room, and Emergency/Trauma Department. The blend of fast output time, adaptable settings, and quick picture seeing make the BodyTom a significant apparatus to any office requiring flexible constant C.T. imaging [74]. By giving constant updates as the medical procedure unfurls, the scanner wipes out the need to transport patients between a working room and radiology suite and assemble a medical procedure more secure. BodyTom can acquire pictures of the whole spine in one move, giving itemized 3D pictures of the pair bone and delicate tissue inaccessible utilizing the level board fluoroscopic imaging regularly found in most working suites. This empowers the specialist to survey any creating intricacies prior to the patient leaves the working room [75]. With this convenient C.T. scanner, you can generally have quick neuromonitoring, even in the littlest clinical focuses.

Machine Learning (ML)-empowered diagnostic instrument

The ML improvement interaction will comprise of different iterative strides for preparing, trial, and foreseeing the likelihood of patients introducing to E.D. with stroke. Exploratory information investigation will assist modelers with understanding element dissemination, multicollinearity among highlights, missing information, information quality. Highlights that are unessential or halfway pertinent (for example, technique codes that are not, at this point in dynamic use), or exceptionally meager can be eliminated or blended. Highlight determination will help lessen overfitting, preparing time, and improve the model exactness. Highlight designing, additionally a significant advance, can be utilized to develop vigorous undeniable level element portrayals from intricate and high-dimensional ideas (for example, analyze, drugs). During the model turn of events, normally, an 80–20 split is performed to test the model exhibition; 20% of the information is set apart as concealed and utilized for model testing, while eighty percent is utilized for the model turn of events. Moreover, as the quantity of cases is probably going to be fundamentally not exactly the number of controls, it is urgent to address the class unevenness. Training prescient models are finished by utilizing the preparation dataset to recognize the best-performing applicant model. Models like calculated relapse, choice trees, irregular woodland, autoencoders, and neural organizations can be utilized in the preparation interaction. Regularly, an interpretable structure, for example, strategic relapse, is utilized for benchmarking. At last, settled K-crease cross-approval applied to eighty percentage of the information ought to be performed for hyperparameter tuning and settling on demonstrating structure decisions – to stay away from the underfitting and overfitting.

Artificial intelligence to improve stroke analysis.

In the United States of America, Stroke is the fifth driving reason for death and a huge reason for serious inability in adults [76]. Rapid determination and therapy of stroke is essential and prompts better results along with anticipation among people handled inside the 'Brilliant Hour' [77]. But there is a problem, strokes, particularly back course strokes, are related to critical (>10%) demonstrative error [78]. The last could be because of (1) a there are patients with intense stroke present with non-central manifestations, for example, wooziness, diplopia, dysarthria, or ataxia, which may not trigger a nervous system science counsel or a requirement for a more point by point neurological assessment; (2) stroke is generally misdiagnosed in more youthful patients; and (3) the crisis division (E.D.) is a difficult climate for suppliers, particularly with the assortment of care conventions, and the unique idea of patient care. Triage, conferences, confirmations, release, and different strides in crisis care are time-delicate, complex, and continually changing to additionally improve viability and nature of care. Consequently, distinguishing potential stroke manifestations can be demanding, particularly when the suppliers are in tutelage. Scoring frameworks for the analysis of stroke and repetitive stroke don't have a high affectability in analyzing the backflow stroke. Furthermore, these devices are likewise not programmed and necessitate that the doctors speculate stroke as a differential finding to apply the scoring framework.

Perhaps one of the most amazing techs is Artificial intelligence (A.I.), computational system importance to copy human understanding. The thought drives the time of enlarged knowledge in medical services that clever calculations can uphold suppliers in conclusion, therapy, and result forecast, particularly with developing computerized and associated quiet information and push on in computational capacities. The increased, indicative model for stroke might be instrumental in low volume or non-stroke focuses' ED, where crisis suppliers have restricted day-by-day openness to stroke. A mechanized P.C. helped screening apparatus that can be flawlessly incorporated into clinical work process to rapidly examine tolerant indications and clinical information and recommend a finding of ('Stroke Alert' spring up) in an E.D. setting could be significant. With this framework, exist the possibility to bring access and convenient finding for the people with the sickness who decide to self-present to an E.D.

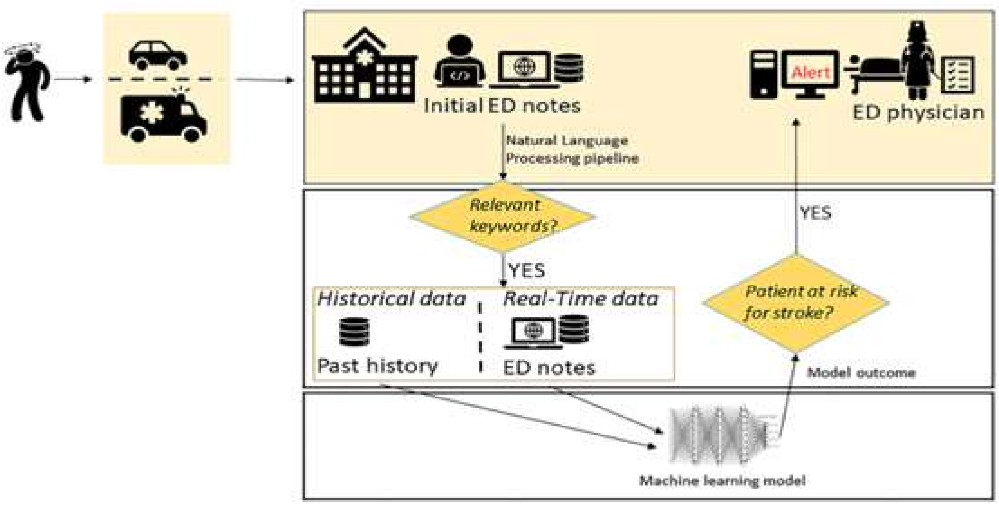

Figure 2: Steps of stroke ML-enabled support system for emergency departments [79].

Challenges

All associations are seeking after high dependability are probably going to confront complex natural difficulties; however medical care supplier associations regularly have their own arrangement of issues.

- Many medical services associations are exceptionally hierarchal, respectful to jobs, and delayed to change that can bargain quality. Leaders might be reluctant to take on offices that are impervious to new cycles.
- Staff may see clashing messages with respect to the needs of obliging doctors, fulfilling patients, and accomplishing monetary goals.
- An absence of plainly characterized and conveyed assumptions and accountabilities for receiving proof-based practices, just as an absence of impetuses for usage, may restrict doctor cooperation and doctor leadership.

- Establishing powerful preparing projects and prerequisites to zero in on proof-based clinical practice and proceeding with schooling on the study of progress can be expensive and seen as troublesome to workers and doctors who have time imperatives. Also, clinics and wellbeing frameworks frequently have high turnover rates and less new groups, making preparing and normalization basic yet challenging.
- Analytic assets might not have the limit or the proper innovation needed to react to all solicitations for the quality program and produce a more significant level examination (past revealing alone) without framework level authority and backing.
- Individual patients respond distinctively to meds, strategies, and treatments, so cards can't be normalized. Similarly, measures in different businesses with unwavering high quality can, for example, carriers and force plants. Additionally, patients' conduct can differ and change over the long haul, particularly in the event that they are attempting to deal with a constant condition, making unusualness and difficulties unparalleled in other industries.
- While HROs intend to forestall and perceive mistakes right on time to maintain a strategic distance from them later on, medical clinics frequently take a review audit of value and, on occasion, endure inadequately planned or insufficient ways to deal with quality.
- Given the quick speed of progress and serious pressing factors, medical services associations are frequently tested to keep up the spotlight on interaction improvement endeavors. Diverting hierarchical exertion and assets to different objectives may hinder the advancement to turning into an HRO.

Conclusion

Neurological emergencies represent a critical danger to each individual's life and freedom. Regularly, such crises strike abruptly, and clinical consideration should be given quickly to limit critical and lasting utilitarian hindrances. As of now, unavoidable postpones needed to acquire corroborative testing sway the speed at which this time-basic consideration can be conveyed. Some medical care researchers guarantee that the solitary reasonable objective of security the executives in complex medical services frameworks is to build up inborn protection from operational perils.

High dependability getting sorted out is one approach to cultivate this inherent opposition. Accepting HRO ideas won't really be simple, there are concurrent pressing factors for cost control just as frequently changing colleagues, and continuous assessment will be required. Regardless, planning strong medical services frameworks by insightfully accepting the focal standards and theory of HROs holds extraordinary guarantee for improving the security and dependability of neurological crises.

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Chapter 13 Ergonomics of Surgical Microscopes

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ABSTRACT

Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies multiple inputs to design to optimize human well-being and overall system performance.Neck and lower back pain are a common problem faced by neurosurgeons involved in longstanding microsurgical procedures. Compromising position and long surgeries are the main aggravating factors. Right ergonomics of surgical microscopes can make surgeries comfortable.Proper ergonomics at surgery improves surgeon's performance. Fatigue and tremors due to poor microscope ergonomics have a huge impact on surgical accuracy and ease of manipulation. This is aggravated when using higher magnification.Number of factors contribute to go microsurgical ergonomics and some of them are:Body posture, support for hands and forearm, direction of upper limb movement causing least stress, muscle loading capacity of fingers and forearm, Hand grip and handle design of microscope, proper skill acquisition and ergonomics of microsurgical instruments. The speed, anxiety, poor confidence, and preceding muscle exertion multiply the chances of easy fatiguability of surgeon.

KEYWORDS Ergonomics, fatigue, operating handle design, surgical

Introduction

Surgical microscopes provide adjustable magnification, brilliant illumination, and clear view of the area of surgical interest and is an indispensable equipment in operating rooms. State-of-the-art surgical microscopes are integrated with various imaging modalities and software's, like tumor fluorescence imaging, augmented reality (AR) for image-guided surgery and intra operative ICG. Also, modern day microscopes have high end optics, shadow-free illumination, stable and flexible mechanical design, and better visualization of nooks and corners.

Surgeries, especially long microsurgeries, not only demand uncompromised concentration of surgeon but also a great degree of physical fitness. Many factors are involved in making microsurgery comfortable and productive.

Ergonomics

The well-designed mechanical system of microscopes offers stability and maneuverability, and the heads-up display gives unmatched ergonomics. Better stereopsis increases the safety of surgery.

A very distinctive advantage of surgical microscope over traditional loupes is the ergonomics which gives a comfortable and flexible working position for surgeons. A microscope helps the surgeon to assume a neutral head-neck posture and maintain a horizontal gaze into the microscope. On the contrary loupes require a flexed posture during surgery. Microscope optics can focus on different planes and differing depths and this avoids subtle adjustments using one's neck to obtain better focus, as with loupes. Assistant surgeons using loupes have a different line of sight, and therefore, the field of view changes. A coaxial view, as in microscopes enables better assistance, coordination, and training.

Maneuverability is important for the simplification of microscope operations. Hence microscopes are equipped with a full range of movements and tilt of the optics, for different heights and positioning needs. Eye-to-object distance is the distance from the surgeon's eye to the focal length of microscope. Surgeons are more comfortable with a longer eye-to-object distance. This also allows use of long micro instruments possible Microsurgery can be performed in either standing or sitting. This is usually the surgeon's choice, but the author prefers standing position in neurosurgery because it allows much better mobility around the operative site, best use of all available exposure from all directions, and fast positional change for operative trajectory, without wasting time in moving the chair around the operative site. These small-time management tactics ultimately contributes to good reduction in operative time. The neurosurgeon adjusts his position often and uses the mouthpiece to fine focus and move the operative microscope head in three axes. Better visual access and easy introduction of long instruments may also require moving the table in various directions. Another trick may be to adjust height by an inch or two by high-heeled footwears (by wearing them or not) – foot stools are seldom necessary. Sitting is more comfortable but reduces mobility and speed of microsurgery thereby increasing the surgical strain. Sitting is preferable in certain instances where surgical trajectory is fixed, operative field is small, and work is done under very high magnification like neurovascular bypass operations and nerve anastomosis. Another advantage of sitting position is the stability of arms and less fatigue.

The benefits of standing position to do microsurgery are:

- Enables greater range of movements for the surgeon and facilitate surgical site access from different directions quickly
- Changing and switching positions is faster.
- Due to increased use of proprioception, the surgeon is better aware of his surroundings.

The parts of a surgeon's body which are subjected to maximum strain when using a surgical microscope are cervical spine, the cervico dorsal junction, shoulder, and neck muscles. As a result, surgeons suffer from pain in the shoulder girdle that may radiate into the arms, disc degeneration, headaches, and exhaustion. The frequently observed anterior position of the head leads to a stressed Atlanto occipital joint. Hyperextension of the wrists should be avoided when using the operating handle as it may cause Tennis elbow.

Operating chairs should be small, mobile, easily maneuverable, and adjustable. The presence of multiple memory function in the chair is an added advantage. The body should be in an upright position, i.e., ear, shoulder and hip should be vertically aligned. The first step is proper adjustment of surgeon's chair. The hip joint should be slightly higher than the knee joint for better comfort. Seat should be inclined in such a position that the pressure is evenly distributed in thighs. The operating table must be set at the right height and working distance between the chair and the table.

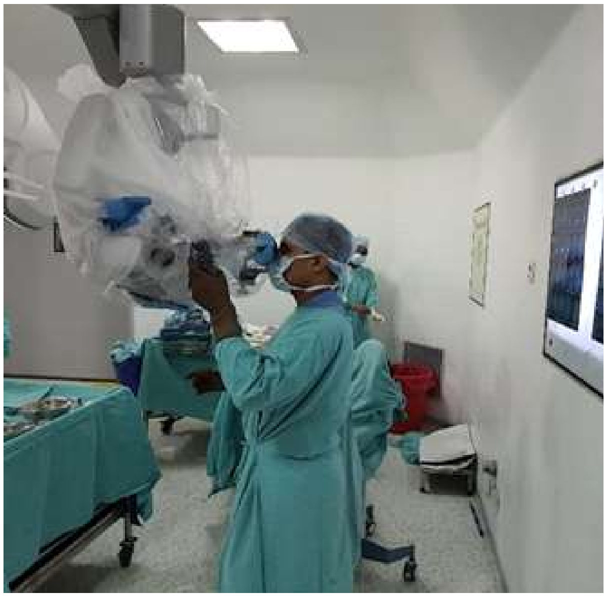

Fig.1 The body should be in an upright position, i.e., ear, shoulder and hip should be vertically aligned.

After these adjustments, the surgeon positions the microscope to maintain an upright posture. The viewing height and angle of the objective and binocular tube is adjusted so that the surgeon can operate in a comfortable upright posture and with the correct working distance. Hence it is important for microscopes have variable binocular tubes and flexible accessories. Handling of microscopes should be user friendly as in many operating rooms several surgeons use the same microscope in succession.

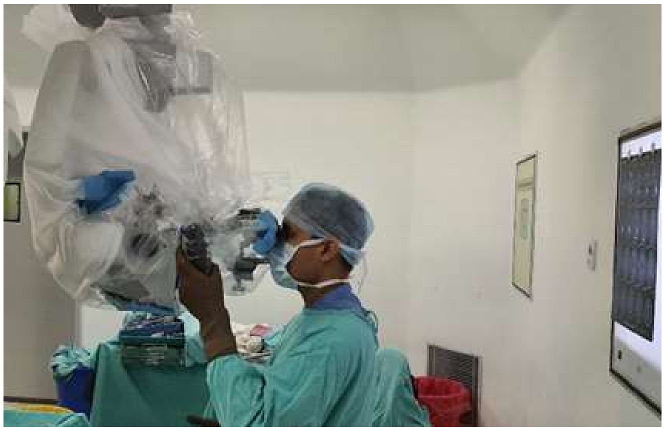

Fig.2 The viewing height and angle of the objective and binocular tube is adjusted so that the surgeon can operate in a comfortable upright posture and with the correct working distance.

Surgical microscopes can be controlled by a variety of ways to facilitate easy maneuverability of the microscope and provide hands free option during surgery. For this the surgical microscopes are equipped with footswitch devices, touchscreen monitors for various selections and settings, and sometimes joystick control for highly precise positioning. Mouth switch is a commonly employed controlling method which provides hands free solution during surgery under high magnification. The mouth switch is used to move the microscope simply by coapting the levers with mouth. Eye controlling is another trend for surgical microscopes.

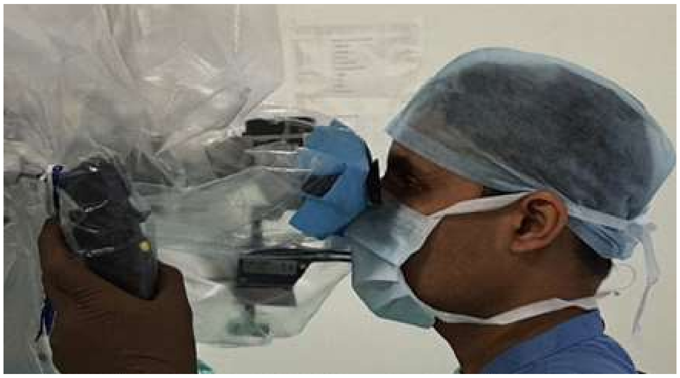

Fig.3 Use of mouth switch.

Factors influencing ease of microsurgery

- Support of finger / wrist/ elbow
- Movement of microscope with respect to the area of interest in operative field
- Ease of rotation of draped microscope
- Strenuous exertion prior to surgery
- Stress, heat, and indigestion
- Cold operating room

Proper Body Posture

Long microsurgical work demands that the back should be straight, elbow joint supported and at level with the arms along the trunk, the wrist partly supported over the head clamps. Proper focus and IPD of microscope are important to prevent strain in eyes. Better support of distal parts of the upper limbs, especially the ulnar aspect of hands, reduces tremors.With experience the surgeon realizes the directions of movement and upper limb posture causing least tremor and this is usually when the distal musculature is used with well supported proximal joints. Unaccustomed strenuous exercises up to 24hours prior to microsurgery can precipitate tremors during fine work with distal musculature.

Surgical microscopes are best handled with one hand, but it requires greater force, especially when moving the optical axis towards the surgeon or when moving it laterally or medially. These issues are due to the non-ergonomic handling and position of the operating handle (OH). To improve the ease of OH handling, the OH should have as little ulnar deviation as possible and at abduction to strengthen the grip and ease of arm rotation. Ergonomics-based OH positioning, i.e., placing the involved muscles in the optimal length-tension relationship, may generate sufficient force for moving the microscope efficiently and reduce arm fatigue.

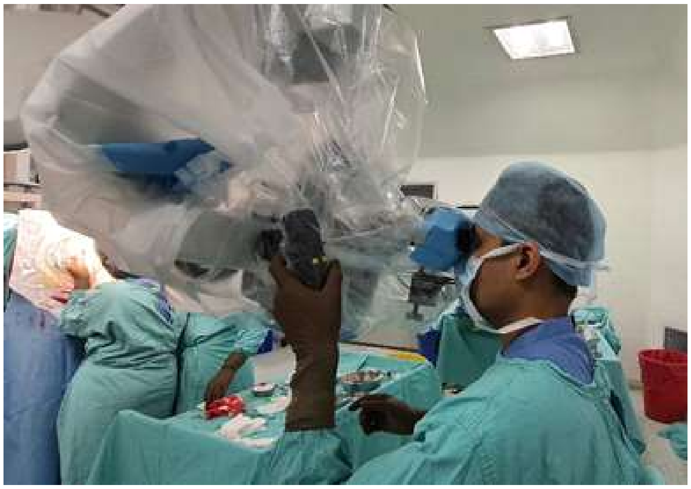

Fig.4 Single handedly maneuvering the microscope.

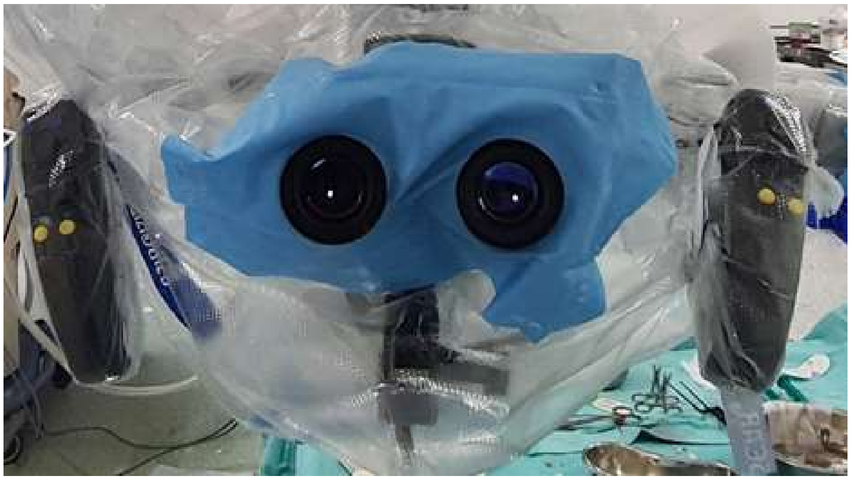

Fig.5 OH should have as little ulnar deviation as possible and at abduction to strengthen the grip and ease of arm rotation.

A new 3-dimensional (3D) technology enables the surgeon to take a more physiologic "heads-up" stance while operating. This is termed as "heads-up 3D microscopy." The surgical microscopic video output is relayed to a high-definition 3D display for the surgeon to view in a more comfortable position. This system is more popular in ophthalmology and its use in neurosurgery is still not in vogue. This innovation in microscopy is not only more ergonomic but also has more educational potential.

Operating microscopes are an indispensable part of modern neurosurgery. Even though there have been huge advancements in optics of microscopes, surgeons are still struggling to match the ergonomics of present-day microsurgical instruments. There is a dire need for creating enhanced and better instruments.

- Fine instrument tips for working in narrow spaces and around sensitive structures
- Better handle design for better grip /with finger mould grip
- Rotatable tips especially for curettes and aneurysm clip applicators
- Improved view of tip of instrument under microscope
- Light weight with sturdy grip
- Nonreflecting material
- Micro instruments with better tactile feedback
- Extremely slim instruments with tubular shafts

The future however shall be much more ergonomically innovative and tempt us to rethink our microscope. 3D heads up display or digital microscopy allows a new level of vision. It provides a superior depth perception, adequate illumination, 2x more information, more efficient workflow, and improved teamwork.

Conclusion

The best of microsurgeons can only give the best possible results if they provide themselves with optimum working conditions. A comfortable posture and a surgical microscope with standard ergonomic features, shall help surgeons to remain focused without getting stressed because of muscle strain and fatigue. The following are the checklist for proper microsurgical ergonomics.

1. Microscope adjustment
   The surgeon should not try to accommodate to manage his microscope, rather he should make the microscope and the working environment adjust according to his needs. As a thumb rule, the microscope should be on surgeons left and instrument nurse/first assistant on his right.
2. Optimal working environment
   The operating table height and the working distance of the microscope should be well adjusted prior to surgery.
3. Microscopes stand position
   Usually, the microscope stand is the bulkiest part and is a hinderance to surgical team mobility. Microscopes with long reach and overhead clearance immensely increases the ergonomics of operating room.
4. Good optics selection to limit eye fatigue
   High quality optics helps avoid eye fatigue and headaches, which may occur after long use of microscope. An apochromatic multifocal lens and high-quality optics provide lighting, excellent adequate depth of focus, and perfect color correction.
5. A compact microscope head
   A short microscope head (distance from eyepiece to objective lens) gives a comfortable position to surgeon. Compact optical head provides a natural, relaxed position and prevents extended out stretching of arms.
6. Customize binoculars settings.
   Each of the ports i.e., side, and back set of binoculars should be well adopted to the assistant surgeon. The primary surgeon should make sure prior to scrubbing that his IPD and eye piece refractive correction is done as per his requirements
7. Visibility for the whole OR team

HD monitors in OR help the entire team to view the surgery and get involved for proper assistance. Choose a large integrated HD monitor with a long and flexible monitor arm.

Key Points

- Good ergonomics in surgical microscopes is not just mechanical but also depends on good microsurgical principles
- Ergonomically designed micro instruments are an important adjuvant to comfortable microsurgery
- Good microscope mobility is important for better ergonomics
- Laboratory training of microsurgical principles reduces stress during surgery
- Proper positioning of operating handle
- Heads up 3D display is the future of better ergonomics in microscopes

Suggested Reading

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Chapter 14 Ergonomics Interventions in Neurosurgical Devices and Instruments

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ABSTRACT

Neurosurgery involves complex surgical procedures and has an impact on functional status as well as social and economic impacts. The best neurosurgical techniques need to be coupled with mechanisms to reduce potential errors to achieve the best results. Human and patient-related factors are non-modifiable, which leaves modifications in instrument design to improve the outcomes. Famous Japanese teaching says that crafting weapons suited for specific wars ensure better performance. Neurosurgical instruments and devices designed in ergonomic principles provide maximal comfort to neurosurgeons and reduces chances of error. This chapter provides an overview of ergonomics in neurosurgical devices and instruments and technological advances fuelled by ergonomic constraints. We also provide an overview of augmented and virtual reality in neurosurgery as it has evolved due to the underlying ergonomics of existing technologies. At the end of this chapter, we wish that readers appreciate the role and importance of ergonomics in neurosurgeons' career, performance, surgical outcome and improved patient's quality of life.

Introduction

Neurosurgery has emerged as one of the most complex surgical procedure with minimal scope of error. Uncontrollable human factors and pathology greatly influence the margin of safety, but instrument factors govern a significant component of safety that can be easily controlled.[1] Therefore, over decades, neurosurgery has witnessed most technological advances augmenting the instruments and device designs to improve the manoeuvrability and dexterity of neurosurgeons[2] As with any other instruments design, neurosurgery instruments need to be resilient, robust, ergonomic, easy to use, , and user-centric. The end-users of these instruments are neurosurgeons, and improvement in patients' safety and better quality of life are the direct benefits. Therefore, the ergonomics have always been the core component in the design of any neurosurgical device or instrument. As the neurosurgical technique advanced over decades, simultaneously, devices and instruments were advanced. Neurosurgical instruments are unique in the sense that both the device designers and end-users happen to be neurosurgeons. As a result, most instruments handle surgical challenges perfectly, and their ergonomic principles are still in use. To enumerate, some of these are Cushing periosteal elevators, Cloward retractors, Penfield dissector, Yasargil microscissors[3] There are severe health impacts of the microsurgical loupes, headlight and operating microscope on the surgeon's cervical spine and musculoskeletal system, often due to postural considerations.

Ergonomical criteria to design neurosurgical instruments

Here, we are limiting our discussion to the ergonomic principles in the design of handheld neurosurgical instruments. The general principles are as follows:

- Optimum interaction between surgeon hand and instrument
- Provision for easy control of gross and fine movements
- Provision for maximal generation of power
- Provision for maximal comfort
- Less fatigue on prolonged usage

There are necessary specifications that should be carefully addressed and adhered to while designing neurosurgical instruments. These include tendon and ligament stress, spinal deviation, linear grip span, maximum grip force, Point pressure, finger recesses, skin pinching, angle of the handle, grip force, weight and size of the instrument, dexterity, use of either hand, surface and texture of instruments, colour coding, and functioning end[4] For a general introduction to specific ergonomic considerations, readers may find the article by Nunez and Kaufman[4] informative.

Designing neurosurgical instruments

The ergonomic design of neurosurgical instruments includes critical steps of design, fabrication, inspection and validation. Plastic instruments can be used for preliminary concept verification and need metal instruments for clinical validation for assessment of its usability, reliability and robistenss[5, 6] To create a new surgical instrument, surgeon specific modification of existing instruments requires 3D scanning, as contours of microsurgical and general surgical instruments are very complex. Contact-free blue light scanners measure these contours with high accuracy, which proceeds for computer-aided designing, prototype fabrication, and part inspection[7] Conventionally, neurosurgical instruments are designed using subtractive manufacturing techniques[8] Concept of co-axial neurosurgical instruments sets was given in 1999 to introduce multiple instruments in narrow surgical corridors where space visible does not get limited due to the size of the instruments[9] Simple modification in the instrument design can significantly influence the ergonomics of the instrument and the safety of the procedure. As with micro forceps, the tips appear large at higher magnification, and the distance between the tips cause them to move out of the surgical viewed. 3D printed ergonomically improved micro forceps provide several ergonomic advantages under higher magnification by changing the distance between the tips.[10]

Ergonomic consideration in neurosurgical instruments based on pathology

Pathologies in the posterior fossa, insula and brainstem offer narrow corridors for standard size instruments to enter. Substantial force is required to remove firm tumours and tumours adhered to the bone. This is not possible often with the use of micro-dissectors and micro scissors. Therefore, it became apparent to neurosurgeons that as the surgical procedure becomes more complex and involves tissues at depth, more ergonomic designs are warranted. We will enumerate a few examples where neurosurgical pathology guided the design of specific instruments, which proved ergonomically safer and more effective than traditional instruments. The detailed description of ergonomics in every neurosurgical instrument is beyond the scope of this chapter.

Rotatable stem micro cup forceps with straight, 45 degrees and 90 degrees tips were designed for brainstem cavernous malformations as surgical treatment for brainstem cavernomas involves working at extreme depths, and the narrow surgical corridor provides a single trajectory for resection.[3] Adequate visualization at depths is also of concern. Development of neuronavigation and bright tungsten light in the surgical microscope provides better visualization at depth. Further advancement includes bright light at the bipolar and malleable suction tip catheter shaft to illuminate the darker areas at depth. Recent advances in endoscopy, exoscope, handheld exoscope and ORBEYE system has improved a lot of the ergonomics of the visualization of the complex neurosurgical procedure.[11, 12] Studies reported ease of performing surgeries and comfort higher than a traditional microscope; however, the disadvantage was of that of operating from the position of the assistant.[11] Ultrasonic aspirators combining high-frequency torsional vibration with specially designed serrated tips allows bone removal at one surface and minimizes injury to nearby vital neurovascular structures[3] This is an essential improvement over the rotating drill used to expand the working corridor in deep-seated lesions[3] Non-stick bipolar and bipolar forceps with high heat diffusion co-efficient incorporates a smooth broad surface with a non-sticking coat and prevents charring and damage in vascular lesions. The problem with the use of surgical lasers was the inability to use them under the surface of a microscope. This has been obviated by changing the ergonomic design of the lasers by using a handheld hollow-core CO_2 laser which can be easily used under the microscope. A suction spatula is described as a third hand with better ergonomics in small intrameatal vestibular schwannomas than a traditional spatula by providing a bloodless field and better visualization of anatomical structures.[13] Retrospective studies found the utility of handheld CO_2 laser in resection of vascular and firm vestibular schwannoma.[14, 15]

Augmented and Virtual Reality in Neurosurgery and its Ergonomics

Neurosurgery speciality witnessed considerable technological advances in the last century to improve patient outcomes.[16] In earlier years, neurosurgical procedures seldom resulted in good clinical outcomes. The impact of morbidity and mortality of neurosurgical disorders on socio-economic aspects of the population laid the foundation for such technological advances. For this to happen, allied specialities needed to advance to a similar degree. Virtual reality (VR) gained importance, as illustrated in Tomlinson et al.[17] of VR-based training modules, in better understanding of neuroanatomy. Though VR was in use for panoramic view in the early eighteenth century, the first VR simulator was a flight simulator invented in 1929, and the term "Virtual reality" was coined in 1987.[18]

The evolution of VR began with the induction of a young electric engineer Tom Furness in the United States Air Force. In mid-1960, he created the first VR system in which pilots can control the aircraft by hand gestures, voice command, and even eye movements by gaining access to the 3D avionics data.[19] This insightful invention credited him with recognition as "Godfather of Virtual Reality".[20] Soon the VR technology evolved and developed into several forms for its utility in the health sector. Robert Mann was the first to introduce a VR system in medicine in orthopaedics, followed by a head-mounted device (HMD) in the 1980s.[21] However first clinical use of VR in the treatment of pathology was in the treatment of spider phobia in 1998.[22] The first use of VR in the treatment of the neurosurgical disorder is relatively recent in 2009 when David. B Clarke excised Left frontal meningioma using Neurotouch neurosurgical simulator.[23] The most typical application of VR technology in medicine in earlier years is dentistry, where it distract patients during the procedure to alleviate pain. Later, several studies expanded on its role in other specialities, including surgical specialities, simulation and training.[20] Throughout the literature, the VR term has been used in a mixed manner indicating VR, AR and even Mixed reality. Though the definition of these terms is different, they are often used interchangeably. VR refers to computed generated 3D immersive environment. AR refers to the projection of computer-generated images onto real-world images. MR refers to the projection of virtual objects into the real world, where the objects are spatially aware and responsive[24] Technical limitations of VR technology and the inability of the human eye to fixate in-depth in a 3D rendered image causes lack of sense of presence noticed in the early usage, nausea, vomiting, and temporarily impaired vision[25, 26] VR needs a frame of reference for interaction with the system where mental process augments real view, and real view augments virtual view resulting in augmented virtuality[17] In virtual reality simulators, the person needs to wear active stereoscopic glasses and hold a set of controllers beneath a partially silvered mirror for visual and haptic feedback. Modifications exist to counter small view, restricted area of work and the absence of head tracking[27] However, these modifications were innovative but unnatural when the operators perspective and image slice gets misaligned[28, 29] The fundamental difference between AR and VR is that the whole sequence is computationally generated in VR, whereas real and virtual images are superimposed in AR[30, 31]

Virtual reality in Cranial neurosurgery

As neurosurgeons ventured into more complex anatomical territories, several gadgets in the form of neuronavigation and advanced neuroimaging have been helpful[32] Yet, a more detailed roadmap of neuroanatomy confers a higher degree of confidence and success in the neurosurgical procedure[33] Therefore, several advancements happened in the last few decades addressing the needs of neurosurgical training and simulation[31, 33] A key challenge faced by neurosurgeon-in-training is to perform a procedure with bi-dexterity in a narrow corridor bounded by complex and vital neurovascular structures and non-resilient bones. Traditional teaching practice for residents is to acquire these attributes is by skilful observation of master surgeons to improve their spatial reasoning abilities.

Neuronavigation is heavily relied upon by neurosurgeons-in-training for planning their approach and localization, while they are not suitable for developing spatial reasoning abilities[31] Virtual reality, when used in simulation and training, proved to be a better alternative to reduce the cognitive load, operative stress duration and enhance efficacy for novice neurosurgeons.[34] VR tools available for neurosurgical education and training include a multifunction head-mounted display (HMD: Microsoft hololens, Google glass), Haptic feedback (NeuroVR, Immersive touch, Procedicus vascular interventional system trainer-VIST), Synthetic tissue simulator (Creaplast, SynDaver, iDU optics 3D printed models, Thomas Jefferson university durotomy repair module), and surgical planning (Surgical theatre, Dextroscope, VPI reveal, Synaptive medical). VR and computer simulation are used in medicine, military, and pilot training to reduce the danger of providing virtual simulator and visual and haptic feedback[35] The challenge often faced by these simulators is that physics-based simulators are very computationally demanding and needs resources in terms of software and computing skills to provide visual and haptic feedback and 3D immersive simulation training[36–38] HMD are the most engaging display in VR, others being google lens, described above, consisting of LED or OLED with a high refresh rate （120 Hz） and 20 milliseconds or less[39, 40] VR systems in use in neurosurgery training and simulation include part-task simulators (e.g., a Ventriculostomy catheter, Subpial resection model), Procedure simulation (Neurotouch), Surgical rehearsal platform (Dextroscope, Virtual endoscopy), and robotic neurosurgery paradigm[41–44] As the surgery progresses, brain shift renders the navigation system using preoperative images less useful[45] To circumvent this problem, an Intraoperative brain imaging system (IBIS) was devised to identify any discrepancy between intraoperative ultrasound and preoperative imaging[46] Using IBIS, the intraoperative stimulation gets modified in real-time and inaccuracies are updated using AR[45, 46] Readers may refer to a comprehensive review of the VR systems for use in neurosurgery simulation and training[41, 47] Two decades back, it has been predicted that neurosurgeons in the future will be trained on VR simulators before actually performing the procedure in the operating room[48] Further VR has an important role to play in tele-proctoring to train surgeons on complex procedures regardless of their geographical location[49] These immersive technologies impact global virtual connection to empower low-and-middle-income countries and potential applications in times of the ongoing COVID-19 pandemic[49] Certain quality control standards should be adhered to while using VR technology as a neurosurgical educational tool.

These include but not limited to high-resolution images, sound quality, haptic and visual feedback, high processing power, internet speed, the structure of the organs and tissue fidelity[50] Key advantages of using VR technology in neurosurgery training compared to human and animal models are its low cost, non-invasive, little repetition, variety, and diversity in cases that can be simulated. However, realism and resolution are an ever-present concern[51] Though more than a thousand articles are published on the use of VR in the medical sector with significant numbers dedicated to neurosurgery; there are no controlled designed studies, high-quality studies with homogenous devices limiting the available evidence on the uses of VR technology in neurosurgery.

VR and Spinal surgery

Research and technical developments in spinal surgery exceed other surgical specialities with advancements in navigation, endoscopy, and robotic spinal surgery. Nevertheless, AR, VR and mixed reality in spine surgery lagged behind orthopaedic surgery in terms of cost-effectiveness, levels of recommendations, evidence, and lack of standardized measures[52, 53] The focus of AR and VR in spine surgery has been on intraoperative visualization of complex and variable spine anatomy and instrumentation[54] Simulation-based training is being developed in a big way to be an effective adjunct in surgical training. Spinal surgery is being more minimally invasive to minimize risk to the patients[55, 56] Pfandler et al[52] enumerated manifold benefits of using VR technology for neurosurgical training and simulation, including a wide range of skills, limited risk for patients, unconstrained training opportunities, better resource allocation, adaptability to trainee's competence and capabilities, better comparability between trainees, unique performance metrics, and research in human factors influencing neurosurgical outcomes[52] Simulation-based training used commonly for spinal procedures in order or frequency are: pedicle screw insertion, vertebroplasty, posterior cervical laminectomy and foraminotomy[52, 57, 58] leading simulator technologies in spinal surgery include Immersive touch simulator, Novint Falcon, Stealth 3D, and Osso VR employing AR, VR and mixed reality techniques[57–60] Gradually, the world has witnessed a parallel increase in literature on VR in minimally invasive spine surgery, spine endoscopy, tumour management and spinal deformity correction[60–64]

Conclusion

Improved ergonomics of hand-held microsurgical and neurosurgical instruments increases the safety and efficacy of the procedure. The ergonomic principles and criteria enumerated in this chapter should guide the optimal design of hand-held instruments during device and instrument design. The primary issue with the industry designing these instruments is the non-awareness of these simple principles. In the end, a brief outline of various augmented and virtual reality techniques currently in use in neurosurgery and how it impacts the ergonomics of neurosurgeons is provided.

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Chapter 15

Ergonomic Equipment Recommendations, Body Mechanics, and Work Simplification Techniques

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ABSTRACT

Work-related musculoskeletal disorders (MSD's) are most common in health care workers, which would decrease their efficiency and even jeopardize their work. Work-related musculoskeletal disorders occur due to poorly designed workspace and equipment. It may affect physicians, surgeons, nurses, dentists, physiotherapists, lab technicians, and other staff involved in treating and managing patients. The scope of ergonomics in healthcare is enormous; it ranges from adequate lightning, noise condition, and naturally to the used equipment and software. There should be accuracy in choosing instruments by medical practitioners, dentists, and the hospital environment. Adequate lighting is essential during surgery; lights with excessive glare can strain the eyes; choosing the instrument's correct length is very important to avoid hand strain or degenerative changes like carpal tunnel syndrome; all surgical instruments should be functional and pleasing and preferably bought from reputed manufacturers. It is essential to identify and eliminate ergonomic stressors wherever possible in a hospital environment. Work simplification implies breaking down complex tasks into simple ones or making work more accessible to avoid strain and pressure due to ergonomic stressors. Some of the work simplification techniques that can be applied are taking a short break in between work, correct placement of screen and microscope, elbow support when sitting for long at the desk, and using proper techniques while performing surgery, e.g., holding scalpel, scissors, and needle holder correctly.

Introduction

Body mechanics is a crucial factor in reducing work-related musculoskeletal disorders and injuries. Body mechanics is the way the body is used while working. Practicing good body mechanics includes maintaining good posture and balance and using larger muscles to do heavy work. Healthcare workers are often involved in lifting or handling patients, which increases the chances of injury, such as back injuries, joint soreness, and muscle strain. Adequate care has to be taken to avoid such injuries, e.g., practicing safe lifting techniques. There is a common misconception that a posture correcting device or chair has to be used, but such devices are found to be more mechanical than beneficial. Instead, one has to develop posture maintaining muscle or paraspinal muscles. Musculoskeletal disorders are painful disorders of muscles, tendons, nerves, joints, cartilage, and spinal discs. According to the Bureau of Labor Statistics of the Department of Labor, musculoskeletal disorders are conditions that occur in the event or exposure due to bodily reactions such as bending, climbing, crawling, reaching, twisting, overexertion, or repetitive motion and does not include any disorders caused by slip, trip and falls. (1) Work-related musculoskeletal disorders cause absenteeism, high turnover rates, and work restrictions, which lead to increased compensation and health cost, a decrease in productivity, and lower quality of life. (2) Since healthcare professionals such as doctors, nurses, physiotherapists, dentists, and others face repetitive trauma and ongoing strains in their routine patient care activities due to working in awkward positions for long hours, are at increased for work-related musculoskeletal disorders. (3)

Overview

Musculoskeletal disorders can be prevented by following good ergonomic practices. Musculoskeletal injuries account for around approximately 40% of the cost of treatment for healthcare workers; also, it is estimated one-third of all sick leaves among healthcare workers are related to musculoskeletal disorders. (2) Types of Musculoskeletal injuries at the workplace are

- Acute injuries such as fractures, strains, sprains, burns, prolapsed intervertebral disc, and lacerations
- Chronic injuries include neck pain, back pain, shoulder pain, chronic fatigue syndrome, and tenosynovitis of the wrist, elbow, or ankle and foot.
- Degenerative changes which include osteoarthritis of the knee, spondylosis, or fibrosis of ligaments

The causes identified that results in musculoskeletal disorders are:

- Acute injuries are caused due to mental fatigue, unsafe furniture, lack of equipment knowledge, and lack of assistance.
- Chronic injuries result from faulty posture, faulty techniques, long hours of work, initial neglect of early symptoms.
- Degenerative changes occur due to prolonged sitting, repeated stooping.

Work-related musculoskeletal disorders can occur in any healthcare worker involved in treating and managing patients. The types of healthcare workers include:

- Mobile workers such as nurses, attendants, porters, and sanitation workers
- Mobile and stationary workers such as physicians, surgeons, technicians
- Stationary workers such as technicians, office staff, laboratory staff, and database staff.

Ergonomic Equipment Recommendation

Ergonomics has a vast scope in the healthcare industry. Over time there have been tremendous changes taking place in the field of healthcare. Technological innovations have increased, and so the complexities are associated with them. Poorly designed equipment has led to an increase in the chances of developing musculoskeletal disorders among healthcare workers. (4) This section will shed light on the importance of proper equipment designs and their usage.

1. Surgical Equipment

Surgical equipment can be either disposable or non-disposable, precisely designed and manufactured, used for cutting and dissecting instruments like scalpel and scissors, grasping instruments like forceps, etc., must be durable, easy to clean, and sterilize to withstand various physical and chemical effects. (5) While choosing dental instruments, ergonomics should be a critical factor that must be considered. Lighter instruments have a larger diameter, and the ones with textured grip surfaces are easier to grasp. It also reduces the amount of force and pressure needed during probing scaling and root canaling. Maintaining dental equipment is equally important; for instance, keeping instruments dental with sharp edges is critical to reducing hand fatigue. Instruments that are not appropriately sharpened will require the operator to apply more pressure to get the same result. (6)

To avoid strain on hands and wrist, two essential things related to surgical equipment should be cared for. First, hands should be trained to handle equipment correctly; in other words, the correct handling instruments should be practiced. For instance, the following technique is followed in conducting a scalpel. The scalpel should be carried like a pencil for short or fine incisions, and the cutting is made mainly with the tip. For scissors: the thumb and the fourth finger should be inserted into the rings, the index finger needs to be placed over the handle to stabilize the scissors. While using Gigli Saw (wire used by the surgeon for bone cutting with two T- shaped handles at either end), the swinging movement should come from the torso and not the elbow or shoulder level; otherwise; it's tiring later painful. The proper handling technique is essential for practical usage and to avoid any strain or pain after surgery. Second, choosing the right kind of instrument is of utmost importance. Ideally, the surgical equipment has to be lightweight, portable, and biomechanical design to become a part of the body while using and not a burden. If the equipment design is faulty, it may lead to excessive strain on hands or degenerative changes like carpal tunnel syndrome. (7)

Dental practitioners can consider the use of automatic instruments such as high-speed handpieces, slow-speed handpieces, belt-driven drills, lasers, ultrasonic scalers, endodontic headpieces instead of making use of manual instruments. (8)The instruments should be anti-glare or dull grey shade, instead of choosing the one with a stainless steel finish; this helps reduce glare. Lastly, all instruments should be functional and in good condition. If the instrument is not well looked after or not in good condition, it will impact the surgical performance and cause unwanted strain. E.g., struggling with a non-cutting scissor can strain the hands. Hence it is essential to choose good quality standard instruments, and they should be sourced from a reputed manufacturer.

2. Workstation ergonomics

Ergonomics plays an essential role in improving a healthcare worker's work efficiency and preventing long-term disability. It is vital to have an appropriate workstation design since a poorly designed workstation can profoundly affect health. The common symptoms of a poorly designed workspace include discomfort in the back, neck, shoulders, hands, wrists, headaches, and features of eyestrain. (9)Some of the essential aspects of a good design of workstation are:

Seat/Chair

The height of the seat should be adjustable. It should be adjusted to make the thighs parallel to the floor, and the seat pan should also be able to move backward or forward as being able to move or change posture, the load of sitting shifts to different parts of the body, that allows the body to recover from extended static postures. (9)The chair's backrest should also be adjustable in height and angles to support the natural curve of the spine. (10) For dental professionals, the patient's chair height and proper positioning of the patient and the dentist are essential. Incorrect positioning of the chair height will lead to fatigue and diminish effectiveness. The dentist's seat should be low enough so that the heels of feet touch the floor. (8)

Desk

The desk height shouldn't be too high, as it may cause strain in the forearms, whereas a too-low desk can cause one to hunch as this will strain the back and shoulders. There should be enough space under the desk for the legs to fit comfortably.

Computer/monitor

Proper placement of monitors on the desk is essential as when it is incorrectly placed, it can cause strain and pain in the neck and shoulder and headaches. Some important considerations for placement of monitor are as follows:

Distance

During laparoscopy procedures, to minimize the neck strain, the best view ergonomically is with the monitor image at or within the 5 optimal degrees below the eye's horizontal plane. (11) The monitor should be placed at a length of 20 inches or at least at arm's length distance.

Angle: The placement of the monitor should be at an angle of around 10-20 degrees, as in case it is placed at a greater angle, it will lead to strain in the neck.

Height: The top of the screen should be at or below eye level, and if one is trying to read the monitor while tilting head back, it can lead to headache or neck pain.

Height of examination table

Different medical specialties will need different types of tables and different heights. E.g., ENT or ophthalmology specialty needs patients sitting with the patient's face and examinee at the same level. Whereas for general surgery or gynecology examination, the examination table's height should not be high enough that the examinee has to lift his shoulders and should not be low enough that the examinee has to bend his back to examine the patient. Specialties like neurology requiring all sorts of positions should be provided with a height-adjustable examination table.

Operation theatre table

The surgeon's comfort is essential for the best productivity from the surgeon. It is more critical when surgery time is prolonged or in scenarios where hand-eye coordination is required, like laparoscopic surgery.

Height adjustment should be surgeon-specific; this may mean different settings in various steps of the same surgery. E.g., during LSCS, the table should be lowest just before the baby's delivery so that manipulations are at the wrist joint rather than at the shoulder joint. The suturing progress table should gradually move upward with skin suturing at a high table position to visualize the operation site better.

Laparoscopic surgery requires special attention to ergonomics

A monitor placed at eye level or slightly below eye level will decrease strain on the neck. Placement of trocars is also essential as it allows proper angulations of hand instruments and thus avoids unnecessary twisting and turning of wrist and hand. The OT table height should be adjusted well because the discomfort caused and operating difficulty is lowest when the instruments are positioned at the elbow height. (11) To ensure smooth instrument manipulation and adequate visualization during laparoscopy, trocars are usually placed in a triangular fashion. The target organ should be 15-20 cm from the center port for placing the optical trocar. The remaining trocars are generally placed in the same 15–20 cm arc at 5–7 cm on either side of the optical trocars. It allows to avoid problems of long handle or too far or too near the placement of ports and the problem of abdominal wall interference. (11)

Body Mechanics

Body mechanics refers to the way the body is used while working. Practicing good body mechanics can help anyone regardless of any occupation or industry. A firm understanding of body mechanics can benefit healthcare professionals by saving them from unnecessary pain and injury throughout their work lives. Doctors, nurses, and other healthcare professionals are engaged in routinely helping the patients by using a range of different motions that can cause harm either to the patient or themselves if not executed properly. Healthcare workers need to know how to effectively use their bodies to acquire greater leverage without causing injury to themselves or the patient. Body mechanics is a crucial factor in reducing work-related musculoskeletal disorders and injuries. Body mechanics involve maintaining good posture and balance and making use of larger muscles to do heavy work. (12)

For healthcare workers, it is imperative to practice good body mechanics for reasons which are as follows:

- A firm understanding of body mechanics is crucial to prevent injuries to both the patient and the healthcare worker.
- Body mechanics involves maintaining proper balance, alignment, and coordinated movement. When a body is adequately aligned, the body parts come in a position that creates optimal balance and function.
- The body's proper alignment reduces stress and strain on muscles, joints, ligaments, and tendons, whether in a sitting position or lying down.

- Proper body mechanics also allows an individual to work effectively without exerting oneself and without hyperextending muscles and joints. (12).
- Improper body mechanics may cause injury to the spine with symptoms such as loss of feeling, movement, and strength. It may also affect other parts of the body and lead to loss of other body functions. Body mechanics are essential since they help protect the spine and other parts of the body.

Application of principles of body mechanics

The scope of application of body mechanics in healthcare is vast. It ranges from standing, sitting, lifting heavy objects, patient handling to using appropriate body mechanics during surgery, and much more. This section will focus on applying body mechanics in different areas of healthcare.

Sitting

Poor posture of sitting can negatively impact a person's health, and it can cause conditions such as rounded shoulders, headache, muscle fatigue, and pain and strain in the neck. In the long term, these minor ailments can lead to severe health conditions due to changes in the spinal cord and increased chances of getting cardiovascular disease. (13) The sitting position usually depends on three factors: the person's height, the type of chair used, and the activity performed when sitting. The posture while sitting can be improved in the following ways: (13)

- The feet should be kept flat on the floor or be rested by using a footrest.
- One should practice sitting with the back straight and avoiding hunching, shoulders relaxed, and buttocks placement at the end of the seat.
- Avoid tilting the head and keeping the head and neck at an upright angle as the head's titling can pressure the neck.
- Knees should be bent at a 90-degree angle and should be kept slightly lower than the hips.
- One should avoid sitting with legs crossed as it restricts the blood flow.
- To avoid pressure building up on the underside of thighs, leave at least a 2-3 inches small gap between the bottom of the thighs and edge of the seat.
- Avoid sitting longer for more than 30 minutes at a time.
- The monitor should be placed so that the first line of the text should be at eye level on the screen. The screen should be at least 20-30 inches away or at least at an arm's length distance.
- Use the 20-20-20 rule that is every 20-minutes spent looking at the

screen, look at something that is 20 feet away for 20 seconds. (13)

- While typing, the hands should be placed slightly lower than the elbow, and fingers should be pointing downwards.

Standing

Our everyday movements affect the alignment of body parts, putting pressure on joints and muscles. This problem can be tackled by having an awareness of our body posture and understanding healthy movement strategies. (14) The way we hold our bodies while standing at a particular place can impact our posture. Below are some ergonomic tips to improve our posture while standing. (14)

- I am bearing body weight primarily on the balls of the feet.
- Keeping knees slightly bent.
- I am keeping feet about shoulder-width apart.
- Standing straight and tall with shoulders pulled down and backward.
- Try keeping head level such that the earlobes should be in line with the shoulders. Avoid pushing your head backward forward or to the side.
- If standing for a longer time, shift weight from toes to the hill or one foot to the other. (14)

Patient handling

Healthcare workers, especially nursing assistants, are involved in patient handling and are exposed to injury from ergonomic stressors while transferring and repositioning patients, leading to musculoskeletal injuries. The possible solution to this includes providing practical training to healthcare workers on proper lifting techniques, minimize manual lifting of patients by using appropriate assistive devices (i.e., using a sliding board, wheelchair with moving arms, alking belts or gaits with handles and heights adjustable electric beds: This has height control that facilitates the easy transfer from bed height to wheelchair height. The bed's size can be adjusted as low to the ground, and it can be raised for interaction with the staff. (15) Some of the lifting guidelines for healthcare workers are as follows: avoid transferring patients when off-balance, lifting loads close to the body, avoid lifting patients alone, using team lifts or any mechanical support, and limiting the number of lifts allowed per worker per day. (15)

Performing procedures

For limiting physical ailments, it is necessary to maintain proper physical, ergonomic movements as well as body positioning, especially for performing a task such as otolaryngology-head and neck surgery that demands repetitive positioning of the body to obtain optimal visual and physical access when operating upon patients, as a result of leaning causes strain on the lower back. During long surgeries maintaining a poor posture such as bending with head forward and excessive leaning with hunched back causing postural impairments leading to musculoskeletal disorders.

Maintaining good posture during surgical procedures involves maintaining the spine's natural curvature, adjusting the OT table height, the even distribution of the body's weight through both legs, use of a small step stool to decrease pressure on the back, and shifting to a sitting position help to get relief from fatigue experienced while standing. (16)

Work Simplification Techniques

Work simplification implies breaking down complex tasks into simple ones and making work more accessible to avoid strain and pressure due to ergonomic stressors. Healthcare organizations demand increasing their operational efficiency and staff productivity. This can be achieved by practicing appropriate work simplification techniques. Using the work simplification technique can allow one to get their work done quickly without much effort. Simplifying complex tasks can save energy, and one can use the same for the necessary activities. Work simplification involves using better and more accessible methods by which work-related tasks can be accomplished. It can be an effective tool to combat increasing costs and increase the performance of the activities that are performed at the workplace. Some advantages associated with work simplification are as follows:

Since complex tasks are simplified, it makes working a lot easier.

- More straightforward job task reduces associated mental and physical stress.
- It enhances the performance and productivity of the employee.
- It helps to achieve specialization.
- It helps in decreasing absenteeism and turnover rates.
- It is a cost-effective method. (17)

Below are some of the work simplification techniques that can be applied in healthcare settings.

Workplace analysis:

This is done to identify and eliminate potential workplace hazards. Assessing the work-related task will include examining the duration, frequency, and magnitude of exposure to any ergonomic stressor, including repetition, awkward postures, vibration, etc., that subject employees to the risk of injury.

Similarly, a record of accidents and injuries can be maintained for analyzing their patterns, and the same can be prevented. (15)

Reducing Workload:

Healthcare workers, especially nurses, physicians, and other job dissatisfaction, can occur due to being overworked, having a poor work-life balance, and sensing that patients do not have enough time for quality care; this, in turn, can contribute to mental and physical stress. Some of the ways of reducing workload are:

- **Cutting down on administrative work**: Record keeping is essential, but it shouldn't consume more healthcare workers than the time spent on seeing patients. Hiring additional staff or outsourcing administrative work can help reduce workload.
- **Changing the way of working**: If the workload size becomes challenging to manage, it can help delegate some of the work to reduce the burden. It is essential to delegate appropriately such that they shouldn't be burdened by the workload, as this wouldn't solve the problem; this just passes the problem to someone else. Work should be distributed between staff which they can perform quickly. (18)
- **Good body posture**: Neutral body posture is an essential element during working on any task.
- Awareness of good body posture is necessary to avoid any kind of musculoskeletal disorders while performing different tasks, which are:
- While sitting: One should maintain a proper hip angle and knee angle. Sitting for more than 30 minutes should be avoided.
- While standing: It is essential to bear the body weight on the balls of the feet and keeping the knees slightly bent; in case if standing for prolonged hours, one should avoid putting entire body weight on a single leg, and body weight should be evenly distributed on both the legs.
- When lifting heavy objects: Lift with legs and not with the back. While carrying an object, hold it closer to the body.
- While performing surgical procedures: Excessive bending should be avoided.
- **Choosing the right equipment**: Choosing the right kind of equipment is important for work efficiency. Some critical factors to be taken into consideration are:
- The instruments should be functional and in good condition.
- Getting good quality instruments from reputed manufacturers is essential.
- The equipment used should be lightweight and biomechanical design.

- Surgical equipment should be an anti-glare/grey dull shade instead of stainless steel that reduces glare.
- Proper placement of the furniture/equipment:
  - Adjusting the height of the seat/desk.
  - Correct placement of the screen and microscope.
  - Using the correct height of the examination and OT table is imperative to avoid musculoskeletal strain.
  - Using proper and safe furniture for both healthcare workers and patients is essential.
- **Prioritizing workloads**: One should prioritize their workload by focusing on the most urgent tasks first. For instance, doctors can attend to most ill-patients first and reduce in-person follow-up appointments or focus on clinical work first over administrative duties.
- **Use of technology**: Technologies can help create efficiency. For instance, electronic prescribing, digitization of records, online ordering, and test result systems can help achieve efficiency. (19)
- **Take a break**: No matter how busy one gets, frequent breaks in between work are important. After every one hour, take a 5 minutes break to take a short walk or do some stretches or breathing exercises. Taking a break is important as it helps the mind and body be refreshed and cut down on stress.
- **Being organized**

It is very important to maximize efficiency. It can be achieved by

- Avoiding Clutter
- It is essential to analyze daily tasks and responsibilities.
- We are setting up a schedule for a specific task, e.g., avoiding checking emails throughout the day and setting up a specific time to reply to emails.
- We are keeping frequently used objects above the hip level to avoid bending.
- Keeping the tools used for work arranged.

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Chapter 16

Recent Advances in Human Factors and Ergonomics in Healthcare

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ABSTRACT

The terms human factors and ergonomics are often interchanged in healthcare, and although there is a slight difference between the two, the essence is the same. While healthcare workers' risks have been looked into regarding work-related disabilities and musculoskeletal disorders and subsequent improvement and adjustment in various medical device developments, applying ergonomics to health information and diagnosis systems can improve patient safety. The safety of all involved, patients and all healthcare staff, is of paramount importance. However, optimal care of patients' wellbeing is only possible when the demand on the healthcare workers' (be they a doctor, nurse, pharmacist, cleaning staff) motor, cognitive and perceptual systems are addressed carefully. Burnout of the healthcare workers is widespread, more so amongst nurses, as the physical and psychosocial aspects of the job affect them the most. This chapter looks into the advances in healthcare ergonomics and human factors, which results in safer practices and less work disability amongst staff, resulting in better services to patients.

KEYWORDS Human Factors, Ergonomics, Healthcare, Disability, Safety

Introduction

Human Factor and ergonomics; these two terms have been synonymously used internationally, although a fine line of a difference does lie between the two. While human factors and ergonomics conventionally deal with workload and posture disorders, recently, HFE has come to deal with psychosocial stress (1) and the improvement in the delivery of health care services. Difficulties in health care delivery are associated with medical errors (2), medication errors (3), poorly designed work systems of nurses (4) and medical residents (5). For quite some time, importance has been put on bad posture in moving and lifting patients on healthcare workers' musculoskeletal health, low back pain. (6); recently, it has come to light that precise and repetitive activities of the hand such as pushing syringes also strain the musculoskeletal health (7,8). In recent years, more light has been shed on the consequences of burnout of healthcare staff on the care of patients; it has been acknowledged that healthcare is one of the professions where burnout has been found to sign along with the teaching profession. (9). These human factors are responsible for the ultimate safety and proper treatment of patients. Advances in human factors and ergonomic have targeted in introducing safer means of sensitive medication disposal; more ergonomically safer means of patient handling; more accessible means of accessing the healthcare system through digital applications and interfaces by the patients; more straightforward means of finding emergency medications, and instruments in critical conditions and most importantly looking into the psychological aspects of burnout and fatigue in health care workers and moving forward to provide safer healthcare practices.

1. Safety

1.1 Patient Safety

The safety of the patients is dependent on how healthcare is delivered. The US institute of medicine has highlighted several major issues when it comes to health care delivery:

a. Medical errors
b. Medication errors
c. Poorly designed work system of nurses and medical residents

The patients' ultimate risk is consistently administering the wrong medication, incorrect dosage, or transfusion of incompatible blood transfusion. Such errors amount to around 7000 deaths per year in the United States of America alone. (10). Human errors due to fatigue, stress, lack of concentration, and too much cognitive load are often the major underlying causes. (11, 12). The WHO and other organizations emphasize that public and private medical institutes should take the utmost precautions to keep all sorts of mishaps to a minimum. In this regard, advances in using pre administered checklists have been made to dispense highly sensitive infusions like intravenous antibiotics, chemotherapy, and blood transfusions. Research has gone underway in this sector to create locked medical containers for blood transfusion bags with sensor lockings and tracking components. (13) A smart barrier is created, which will only be removed if all the checkboxes are ticked; this will minimize the errors due to human errors. A central processing unit will be matched to the information placed in an electronic device worn by the patient (maybe a bracelet or locket). Once the information is matched, the container can only be opened and the medication dispensed.

1.2 Healthcare Worker Safety:

Low back pain and postural pain due to incorrect handling techniques and heavy equipment or machinery are some of the most typical causes of absenteeism from work. High physical activity like lifting severe patients or moving rich beds can result in a poor distribution of weight which produces fatigue and disinterest in work. The Center for Ergonomics of the University of Michigan has developed a software program called 3DSSPP (Static Strength Prediction Program) to address these issues. (14). This software breaks down tasks dealing with the manual lifting of loads or using specific postures into subtasks and analyses how much force is required by the worker concerning their different body parts. This allows health care workers to be given tasks suited to their abilities, and hence there will be no compromise to their state of health.

2. Healthcare Information Systems:

A significant player in the appropriate manner in which healthcare is delivered is the availability of health information. The world wide web has brought about an immense advancement in the healthcare system regarding access to information and aids in treatment.

2.1 Use of artificial intelligence in remote care support:

Patients with dementia are vulnerable to losing their sense of direction and dealing with day-to-day activities. iWander (15) is a mobile tracking app for people with dementia. The patients wear devices around their necks as lockets or bracelets; their daily routines are monitored, and these data are recorded centrally. If there is a deviation from the usual practice for some reason, an alert is activated, informing the concerned caregiver. These tracking systems also come in with inbuilt weather applications which can detect the climate beforehand. Thus if an individual's daily routine included going out for a walk, the application would alert the individual to take an umbrella if there were to be going outside at a particular time or to wear a heavy coat in case of a windy day.

2.2 Digital Wayfinding Systems:

Wayfinding systems have been used in hospitals to guide patients and attendants to their destination by using the best route and identifying their location. This has been used in arrows and signs displayed in hallways, corridors, and walls. Wayfinding systems have progressed to using interactive interfaces, kiosks, and even mobile software apps. Interactive touch screen displays at the entrance of busy hospitals can guide new patients or attendants coming to visit. Although the healthcare system has made a significant investment in establishing these wayfinding technologies, a lot depends on the ease of utilization and avoidance of medical jargon for the commoner. The effective use of ergonomics and human factors can ultimately provide safer health practices to the community.

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Chapter 17 Computer Vision Syndrome an Evolving Condition among Healthcare Workers

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ABSTRACT

In the modern era, computers and other digital devices are being widely used by a large number of individuals including doctors, nurses, healthcare technicians, clerical staff in hospitals and other healthcare workers (HCW's). Our dependence on these digital devices has increased so much that whether it is for education, work, or socializing and entertainment; we all require computers, smartphones and other digital devices. This has led to a large number of people having eye symptoms such as eye strain, burning sensation, redness or grittiness as a result of digital screen usage. All these symptoms plus some non-ocular symptoms associated with digital screen usage together are referred to as computer vision syndrome or digital eye strain.

Introduction

Computer vision syndrome as defined by the American Optometric association is, 'a complex of eye and vision problems related to the activities which stress the near vision and which are experienced in relation or during the use of the computer.'[1]

Symptoms of CVS

The most common presentation of CVS is dry eyes, burning sensation,headache and blurred vision. Non ocular symptoms include back, shoulder and neck pain.[1,2,3]

For easy understanding of the cause and symptoms, Blehm et al[4] has classified the symptoms of CVS into four categories as seen in Table 1.

Table 1

Category	**Symptoms**
1. Asthenopic symptoms	Eye strain, tiredness and soreness of eyes, headache
2. Ocular surface related symptoms	Burning, dryness, gritty sensation, watering and redness of eyes
3 Visual symptoms	Blurred vision, diplopia, difficult refocusing after prolonged near work and transient myopia
4. Extra-ocular symptoms	Neck, shoulder and back pain

Pathophysiology of CVS

The symptoms of computer vision syndrome can be explained by one of the following mechanisms[4]-

1. Accommodative mechanism
2. Ocular surface mechanism
3. Extraocular mechanism

Accommodative mechanism: Spasm and fatigue of the ciliary muscles of the eye, which help in accommodation by changing the shape of the crystalline lens occurs due to prolonged accommodation from constant near work. This is responsible for asthenopic and visual symptoms of computer vision syndrome such as eye strain, headache, blurred or double vision, transient myopia and difficult refocusing at distant objects after prolonged near work.[4,5]

Ocular surface mechanism: The blink rate in a normal individual is usually in the range of 16-18 times/minute. An individual who is concentrating on a digital device such as a computer or smartphone for long hours tends to blink only about 6-8 times/minute. This leads to increase in the rate of evaporation of the tear film and gives rise to dry eye and ocular surface related symptoms such as burning sensation, redness, grittiness and foreign body sensation in the eyes.[1,4,5]

Extraocular mechanism: These symptoms arise as a result of improper positioning of the computer screen, wrong desk or chair height and design, bad posture, inadequate lighting and glare from surroundings. These include musculoskeletal symptoms such as neck, shoulder and back aches.[1,4] It is also important to note that any image or letter on the computer is made up of hundreds or thousands of tiny dots or pixels which join to form an image or letter. Hence the quality of the object or image is sharpest in the center and diminishes towards the periphery. This difference in resolution requires a greater visual demand from the viewer[5,6], which may be responsible for some of the symptoms of computer vision syndrome. Other contributing factors are glare from the computer screen, contrast and background lighting.

Predisposing factors for CVS

Computers and digital devices are a very important part of our lives; both at work and home. The prevalence of CVS ranges from 64-90% among computer users.[7] An individual using the computer screen or any other digital screen for more than 2 hours a day may be predisposed to computer vision syndrome. CVS is seen in about 70% computer users worldwide.[4]

The predisposing factors for CVS can be classified into:

- Personal factors
- Environmental factors
- Computer related factors

Personal factors

Long hours of computer usage (>4 hours), computer usage beyond work hours, night shifts and on-call duty, bad posture, wrong viewing angle, advanced age, female gender, especially peri- and post-menopausal women, associated ocular conditions (uncorrected refractive errors, dry eye disease, meibomian gland dysfunction, contact lens usage), systemic conditions (rheumatoid arthritis, SLE, other collagen vascular disorders, thyroid dysfunction), eye surgeries or laser therapy in the past (post cataract surgery, refractive surgery such as LASIK or retinal photocoagulation therapy), systemic medications (diuretics, anti-histamines, psychotropic, and antihyp erten sives).[8,9,10,11] Since a of ide variety of the above factors could be present in health care workers in the older age group, CVS appears to be more prevalent in the senior health care workers.

Environmental factors

Working in sterilization unit with exposure to chemical disinfectants, medical records department with exposure to dust, laser and photocopy toner, building contaminants, air borne paper dust, working in departments such as radiology, blood bank or pathology which require one to use digital screens for long hours for the purpose of data entry and reporting, presence of dry air, direct exposure to air conditioner, glare from background lighting, inadequate lighting, poor ventilation.[12]

Computer related

Poor resolution, poor contrast, and delayed refresh time of the digital device are some contributing factors.[13]

Prevention and Management of Computer vision syndrome among health care workers

Points to be remembered are: (5 E's)

- Eye examination
- Exercises
- Ergonomics
- Effective breaks
- Eye wear

Eye Examination

All healthcare workers should undergo periodic eye examination. This is especially important for departments such as Radiology, Pathology, Microbiology, Ophthalmology, Medical records department, registration counter staff and sterilization unit apart from other departments. All HCW's involved in tasks which require long hours of digital screens should be evaluated by an Ophthalmologist prior to their placement. National Institute of Occupational Safety and Health (NIOSH) guidelines state that a computer user should be screened by a qualified Ophthalmologist before he starts working on the computer and thereafter annually.[14]

It is seen that in individuals who have a refractive error, however small it may be; the symptoms of CVS seem to be precipitated earlier than other individuals and are of greater severity. Hence after a detailed eye examination the individuals have to be prescribed necessary spectacle correction and counseled to use spectacles or contact lenses whenever using digital screens or constantly as per individual needs. These individuals have to undergo an eye examination annually or as suggested by the treating Ophthalmologist depending on signs and symptoms of CVS or other associated ocular conditions.

Ergonomics in management of CVS

The screen should be placed at a distance of at least 20-28 inches from the eyes.[15] In the case that a document or any reading material is being referred from, it should also be placed at the same distance from the eyes. Using a document holder placed at the side of the computer screen will minimize the need for constant movements of the head and neck while shifting gaze from the monitor and the reading material.[14] The screen height should be adjusted such that the screen is 10-20 degrees below eye level. This placement requires one's head to be slightly tilted forward while looking at the center of the screen [15,16] thus allowing the neck muscles to relax.

The screen should not be higher or lower than this level. A screen placed higher than this level will increase rate of evaporation of tear film and worsen the ocular surface related symptoms of CVS, whereas having to bend one's neck in case the screen is placed lower than 20 degrees from the eye level will give rise to musculoskeletal symptoms of CVS. It is helpful to use adjustable furniture which will help assume a comfortable posture and reduce strain on neck, shoulder and back muscles. The back, neck and head should be well supported by the chair.[15]

The height of the chair and office table should be adjusted such that the back is erect, the thighs are parallel to the floor, the knees are bent at 90 degrees and feet placed flat on the floor or supported on a foot rest. With the back supported and whilst sitting straight, the arms should be placed on the armrest and elbows bent at 90 degrees.[14,15,16] There must be a padding or sponge before the keyboard so that one's wrist can be comfortably rested on the padding. The keyboard and mouse should be located lower than the elbow and within easy reach of the hand. When the wrists and forearms are rested on a hard surface damage to soft tissues, nerves and vessels can give rise to tingling sensation and numbness of the fingers. Hence the padding below one's wrist helps to minimize such injuries by giving a soft contact surface.[15,16]

Measures to minimize glare

In general, the background lighting intensity of the room should be less than the normal lighting in any room. Lighting levels between 200 and 700 lux measured at the workstation are recommended. More than 500 lux will only be required for reading poor quality documents.[17]

Anti- glare coating or anti-glare hood can be fitted on the computer screen to minimize glare from the screen.[17] Sunlight from the windows should be directed away from the screen and from the user's eyes. This can be ensured by having the windows at the sides rather than in front or behind the computer screen. The overhead lights should be adjusted such that they are directed away from the computer screen and away from the user's face. The screen contrast should be optimum. A too bright or too dim contrast makes the user have to adjust constantly to the contrast and may worsen eye strain and cause ciliary spasm.[16]

The font should be legible enough and should be adjusted according to the user's requirement. It is very important that the computer screen is cleaned regularly and freed from dust particles which tend to settle on the screen.[17]

Eye Exercises

20–20–20 rule: After every 20 minutes, one must look away from the computer screen for at least 20 seconds at an object located at 20 feet. This helps in relaxing the ciliary muscles which are fatigued as a result of constant accommodation from continuous near work.[18,19] Another exercise is to look at a far object for 10–15 seconds, then look at a near object or the computer screen for another 10–15 seconds followed by again looking at the distant object. This exercise when done about 10 times in between one's shift will help by preventing accommodative spasm and reduce asthenopic symptoms of CVS. One should also voluntarily blink several times every one or two hours in order to replenish the tear film which is depleted as a result of infrequent blinking and evaporation.[20]

Effective breaks

Giving one's eyes and body short and frequent breaks, as short as 5minutes every one hour will help reduce symptoms occurring as a result of accommodative spasm, infrequent blinking and musculoskeletal symptoms.[18] During these breaks one may just stand up from sitting position, stretch one's back and neck muscles, drink water or interact with colleagues. If such an opportunity is not available, one may just look away from the computer screen every 20 minutes and blink voluntarily.

Eyewear and eye drops

Any refractive error that is detected by the Ophthalmologist must be prescribed and the HCW should wear the correction at all times and especially while working on digital screens. Individuals using contact lenses reported a higher prevalence of CVS and dry eye disease as compared to spectacle users. Hence a shift over from contact lenses to spectacle wear may be considered.[21] Presbyopes should be given near addition lenses. The conventional bifocals may not be of much benefit as there occurs an image jump when shifting gaze from a near to distant object.

Also bifocals are designed to view objects at a distance of 16 inches and an angle of 20 degrees from the eye level; however the computer screen is to be placed at a distance of 24 to 28 inches away from the eyes.[22] Hence, progressive addition lenses are preferred where the dioptric power progressively changes in a gradual manner from distance to near correction and they also provide clear vision for intermediate distances. Recently, occupational progressive lenses are also available which have a large area on the top part of the lens which enables one to view intermediate distances (such as the computer screen) clearly and the lower portion enables near vision.[23,24] The newer types of lenses are the blue light blocking lenses. These come with a special coating which reduces the glare and light intensity arising from an average digital screen. They also have a UV blocking coating which blocks the UV rays produced by these screens from reaching the user's eyes. Artificial tears or lubricating drops (0.5% or 1% carboxymethylcellulose, polyethylene glycol, polyvinyl alcohol or sodium hyaluronate) may be instilled in between shifts to alleviate ocular surface related symptoms such as burning sensation, grittiness and redness.[25,26]

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Chapter 18 Gender Based Human Morphological Variations for Ergonomics

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ABSTRACT

Differences between males and females are the most striking aspect in the anatomy of the musculoskeletal system. The gender-based variations are responsible for the different types of musculoskeletal disorders among males and females. Generally, the male skeleton is more massive and heavier than that of female. The bony elevations like tubercles and trochanters, produced by the insertion of muscles will be more highlighted in men. Females have a larger pelvic inlet and outlet to allow for childbirth. It is essential to understand the gender-based variations to deal with the ergonomics. The variations in the parameters of components of the male and female musculoskeletal system will be described in this chapter.

TEXT:

Gender differences are most striking in the Anatomy of the Musculoskeletal system. The differences are mainly in the composition of bone. Generally, men have more bone and muscle mass and less fat mass compared to women.[1] Male skeletons are more massive, impressions, elevations and depressions are more accentuated due to highly developed musculature. These differences are mainly due to the effect of sex hormones on the metabolism of bone and skeletal muscle.[2] These gender differences in structure and strength have some impact on the work performed by them. Olden days, women were involved in work that involved repetitive tasks of low physical strength like food preparation, domestic works, basic agricultural tasks etc, whereas men were involved in jobs that require more physical strength like carrying heavy loads, walking long routes, hunting, fishing, war etc. But with the increase in the number of females taking part in jobs that require more vigour, expertise, and increasing physical strength like sport at all levels, the chances of females being injured has increased over the years. Women have higher chances of injury in the majority of sports than men[3,4] which suggest that the anatomic and physiologic differences between the two genders plays an important role.

The most significant difference between the male and female skeleton is present in the bony pelvis.

Female pelvis is more adapted for pregnancy and childbirth. It is roomier and all measurements at the inlet, cavity and outlet will be more in female. The following table depicts the differences between male and female pelvis.[5]

Features	Male	Female
Pelvic bone	Heavier	Lighter
Iliac fossa	More concave	Shallow
Anterior superior iliac spine	In-turned	Straight forward
Greater sciatic foramen	Angle (50.4°) and depth are narrow	Angle (74.4°) and depth are wide
Ischiopubic ramus Ischial spine	Thick and more everted In-turned	Thin and nor much everted Out-turned
Acetabular cavity	Large	Small
Distance from medial surface of pubis to anterior margin of acetabulum and transverse diameter of acetabulum	Equal	Distance is longer than transverse diameter of acetabulum
Obturator foramen	Large and oval	Small and triangular
Preauricular sulcus	Barely visible	More prominent
Body of pubis	Elongated	Short

Subpubic angle	**50°– 60°**	**80°– 85°**
Distance between pubic tubercle	**Less**	**More**
Articular surface of first sacral vertebra	**Large and greater than ala of sacrum**	**Small and equal to ala of sacrum**
Sacrum	**Long and narrow**	**Short and wide**
Curvature of pelvic surface of sacrum	**Uniformly concave**	**Upper part is flat and lower part is abruptly concave**
Sacral index （Maximum breath÷ Maximum length ×100）	**105**	**115**
CoccyxSacroiliac joint	**ImmovablePermits limited movement**	**MovablePermits rotatory movement during pregnancy**
Pelvic inlet	**Heart shaped**	**Round shaped**
Antero-posterior, oblique and transverse diameters of Pelvic inlet	**0.25inch shorter than that of female**	**Longer than that of male**
Pelvic cavity	**Longer and more conical**	**Shorter and more cylindrical**
Ischiopublic index （Length of pubis÷length of ischium×100）	**Less than 90**	**More than 90**

Pelvic outlet	**Small**	**Wide**
Pelvic outlet- Antero-posterior, oblique and transverse diameters	**1 inch shorter than that of female**	

Skull bone is the second-best bone for determining the sex of an individual next to pelvic bone. The following features shows significant differences between male and female skull bones.[6,7]

Features	**Male**	**Female**
Weight	**Heavier**	**Lighter**
Forehead	**Sloping**	**Vertical**
Frontal eminence	**Small**	**Large**
Supraorbital/superciliary arch or brow ridge Glabella	**More prominent** **More prominent**	**Less prominent** **Less prominent**
Frontal air sinus	**Larger**	**smaller**
Infraorbital margin	**Blunt**	**Sharp**
Orbital opening	**Square**	**Round**
Parietal protuberance	**Less**	**More**
Zygoma	**More prominent**	**Less prominent**
Temporal line, nuchal line	**More prominent**	**Less prominent**
External occipital protuberance	**More prominent**	**Less prominent**
Mandible a. Coronoid process b. Mental protuberance c. Chin d. Alveolar process e. Angle of mandible	 Larger More pronounced Square Larger 90°	 Smaller Less pronounced Rounded/pointed Smaller >90°

Even though the pelvis and skull bone show significant morphological differences between gender, the long bones of upper and lower limbs have also been subjected to both the morphological as well as metric analysis in the determination of sex. Cross sectional area of long bone is greater in men, which may be due to the greater rate of appositional growth from periosteum from puberty onwards.[8]

Humerus

In a study done in Maharashtra region of India (Ahmad SS)[9], the following anthropometric differences were found between male and female humerus, which were almost similar to the study by (Reddy et al)[10] in the same region. The differences are tabulated below.

Parameters	**Male**	**Female**
Weight (gms)	**107.82 ± 18.10**	**71.96 ± 13.31**
Length (mm)	**312 ± 14.78**	**283 ± 17.91**
Vertical diameter of head (mm)	**43.28 ± 2.26**	**37.41 ± 2.78**
Transverse diameter of head (mm)	**40.12 ± 2.03**	**34.33 ± 2.63**
Circumference at anatomical neck (mm)	**131.83 ± 6.15**	**115.2 ± 7.88**
Circumference at surgical neck (mm)	**90.84 ± 6.3**	**79.98 ± 7**
Width of bicipital groove at the level of surgical neck (mm)	**10.54 ± 1.47**	**9.37 ± 1.37**
Circumference of midshaft (mm)	**60.84 ± 3.72**	**53.28 ± 4.71**
Anteroposterior diameter of mid shaft (mm)	**19.29 ± 1.36**	**17.11 ± 1.66**
Transverse diameter of mid shaft (mm)	**18.84 ± 1.46**	**16.04 ± 1.5**
Bi-epicondylar distance (mm)	**59.95 ± 3.45**	**52.57 ± 4.36**

Trochlear width (mm)	**24.56 ± 1.39**	**21.22 ± 1.71**
Capitulum width (mm)	**23.23 ± 1.23**	**20.98 ± 1.96**
Maximum width of lower end articular surface (mm)	**40.82 ± 2.08**	**35.3 ± 2.85**
Height of medial flange of Trochlea (mm)	**7.98 ± 1.41**	**8.28 ± 1.28**

All the parameters measured were greater in male compared to female except for length of medial flange of trochlea, which was slightly more in female. This is the reason for the increased carrying angle in females.

Radius

In studies done at Chennai region of India by Ramya et al[11] the following differences were found between male and female. These findings were similar to the finding by J.E. Waghmare et al[12] in the same region.

Parameters (mm)	**Male**	**Female**
Maximum length	**25.14 ±1.43**	**23.2 ±**
Maximum diameter of head	**2.74 ± 0.07**	**2.5 ± 0.02**
Circumference at radial tuberosity	**50.08±2.58**	**44.89±2.9**
Anteroposterior diameter of radial tubero sity	**14.13±0.92**	**12.38±1.62**
Vertical diameter of radial tuberosity	**22.53±1.25**	**20.12±1.16**
Mid-shaft circumference	**41.89 ± 3.42**	**36.52 ± 2.68**
Anteroposterior diameter of mid- shaft	**11.56±0.92**	**9.63±0.84**
Transverse diameter at mid-shaft	**13.67 ± 0.44**	**11.97 ± 1.03**
Width at distal end	**3.72 ± 0.04**	**3.28 ± 0.06**

Ulna

The following differences between male and female ulna were recorded by the authors Rashmi Srivastava et al[13] in Varanasi region of India.

Parameters (mm)	Male	Female
Maximum length	262.0 ± 13.9	236.8 ± 9.80
Circumference	33.95 ± 2.27	31.15 ± 1.91
Trochlear notch length	35.00 ± 2.18	31.40 ± 2.64
Radial notch height	11.68 ± 1.51	9.61 ± 1.49
Radial notch width	17.63 ± 1.72	13.86 ± 2.35
Coronoid height	33.6 ± 1.92	31.22 ± 2.14
Olecranon width	24.11 ± 1.80	21.21 ± 1.87
Distal articular width	16.47 ± 1.25	14.5 ± 1.09

Lower limb

As the pelvic cavity is wider in females, the distance between the acetabular cavity of hip bone is more, which in turns increases the distance between the greater trochanters and the width of the hip. This impacts on the position of the femur, they are at a greater angle than men.

Wider hip and more angled femur is responsible for the genu valgum in females. The following morphometric differences were found in the femur in an Indian study by Sikka A et al.[14]

Femur

Parameters (mm)	Male	Female
Maximum length	47.04 ± 2.38	42.72 ± 3.13
Maximum breadth at upper end	9.08 ± 0.54	8.07 ± 0.51

Head- Vertical diameter	**4.38 ± 0.26**	**3.83 ± 0.28**
Head- Transverse diameter	**4.40 ± 0.25**	**3.84± 0.29**
Neck- Vertical diameter	**3.13 ± 0.21**	**2.64± 0.28**
Mid-shaft diameter	**2.85 ± 0.25**	**2.44 ± 0.25**
Epicondylar breadth	**7.76 ± 0.46**	**6.89 ± 0.40**

Tibia

Seema et al (2012)[15] found the following gender differences in adult tibia on the right and left side in Punjab zone.

Parameters (mm)	**Male**		**Female**	
	Right	**Left**	**Right**	**Left**
Weight (gm)	**234.26 ±48.043**	**224.81± 50.06**	**163.99 ± 38.59**	**157.25± 35.78**
Length (cm)	**38.11 ± 1.9**	**37.47 ± 1.97**	**33.94 ± 2.18**	**35.06 ± 2.11**
Mid-shaft circumference (cm)	**7.53 ± 0.53**	**7.59 ± 0.519**	**6.11± 0.567**	**6.61 ±0.52**
Upper end width (cm)	**7.35 ± 0.359**	**7.13 ± 0.269**	**6.41 ± 0.47**	**6.51 ± 0.43**
Lower end width (cm)	**4.91 ± 0.413**	**4.81 ± 0.66**	**4.32 ± 0.30**	**4.33 ± 0.27**

Fibula

In a south Indian study on adult fibula to determine the sex by Aparna et al[16], the following differences were recorded.

Parameters (mm)	**Male**		**Female**	
	Right	**Left**	**Right**	**Left**
Weight (gm)	**49.9**	**43.0**	**33.0**	**34.0**
Length (cm)	**36.1**	**36.1**	**33.5**	**33.3**
Mid-shaft circumference (cm)	**3.9**	**4.0**	**3.3**	**3.2**
Upper end width (cm)	**2.4**	**2.5**	**2.1**	**2.1**

Other than long bones, dissimilarities are found in the female vertebral column. Lumbar curvature is more accentuated in them. Body of the lumbar vertebrae is smaller in females and also the bone density. Which may be the reason for the higher chances of lumbar vertebral disorders like fracture, disc prolapse in women compared to men.[17]

The skeletal differences between men and women in Indian population is explained in this chapter. The differences in anatomy of bone, joint, role of sex hormones are considered important in the different types of presentation of musculoskeletal disorders in male and female. These factors are also important for the diagnosis and management of ergonomic related disorders.

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Chapter 19 Safety Culture in Healthcare Delivery Systems

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ABSTRACT

The Healthcare Professionals have roles and responsibilities which go beyond patient care. These are managed not just by doctors but also by administrators, technicians, counsellors, technical officers, nurses, field staff etc. Also, health care delivery system include wellness centres, sub centres, primary health centres, CHC, district hospitals, medical college attached tertiary health care centres and corporate/ private clinics and hospitals. The availability of healthcare facility being mainly concentrated in urban areas, shortage of healthcare professionals and increase in chronic conditions have increased the workload of healthcare providers and overall decreased the organizational performance for coordinated patient care. With COVID-19 pandemic and day to updates on mutation, its function is very much affected. Hospital safety is a system of safeguarding or preventive measures taken to protect hospital health care workers from hazards or reduces the exposure to risks and also it prevents nosocomial infections. In healthcare delivery systems, safety systems must be provided to neutralize the physical hazards in terms of fire safety, electrical safety, chemical safety, gaseous safety; and the procedural hazards from occupational exposure of infection and from bio-hazardous materials. The systems must be put in place for workload management and to reduce work related injuries. Ergonomically designed medical devices, equipment and technologies contribute to improving the working environment in hospitals by increasing effectiveness, efficiency and timeliness both for the patients and the providers. There is an emerging role of ergonomics in redesigning healthcare delivery systems for safety culture of health professionals for increasing the quality of work life and it has become more important in COVID-19 Pandemic era. All the aspects have new dimensions added by COVID-19 pandemic.

Introduction

Healthcare is one of the most complex industries in our world. Health care workers includes not just doctors but also by administrators, technicians, counsellors, technical officers, nurses, etc who have roles and responsibilities beyond patient care. We must safeguard our patients as well as healthcare workforce by eliminating hazards in healthcare delivery system. Safety and reliability of health care facility is important for the patients and their attendants, to have faith as well as trust that they will receive optimum patient care and safety.

It is equally important for the clinical and the non-clinical staff have conducive and safe working environment where they entrust their livelihoods. There is an emerging role of ergonomics in redesigning healthcare delivery systems for safety and security culture of health professionals for increasing the quality of work life.

This enables good working environment, providing continuous learning opportunities, good leadership, and ownership by the administration of health care delivery systems towards the entire healthcare workforce. The emerging role of overall wellbeing of the health care professionals as part of safety culture is especially important and to include stress management and development of excellent resilient system for overall development. Safety culture should also involve IT technology related issues, privacy, confidentiality, data security etc which may not be possible to discuss in larger details but it is very important to have system and legal framework in place.

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History of Ergonomics in Health Care delivery system

Safety culture in health care delivery system dates to Hippocrates. Hippocrates had recognized the potential for injuries that could arise from the well-intentioned actions of healers. He drafted the Hippocratic Oath and pledged to: "prescribe regimens for the good of patients according to my ability and my judgment and never do harm to anyone." Since then, the directive primum nonnocere ("first do no harm) has become a central tenet for contemporary medicine. In 1863, Florence Nightingale warned about the requirement in a hospital is that should do the sick no harm.

The quality pioneer Dr. Edwards Deming – "Never-ending cycle of continuous improvement" in health care delivery system. Currently, the organisations are undertaking "evidence-based" initiatives to improve the working and safety conditions of hospitals and healthcare workers. Evidence based initiatives are evolving over a period of time and it is fast changing in health care delivery system and hence fast acceptance and required changes have to be done. It is seen many times that by the evidence-based initiatives are applied in the practice they become outdated and it keep running for years. The culture of incorporating evidence-based initiative on timely basis is an important safety culture required for health care delivery system. There should be culture of generating evidence-based initiative rather than merely accepting the same from western world.

Healthcare Delivery system

Healthcare delivery is done through health infrastructure, which is categorized as – i) Physical infrastructure and ii) Human resources. The health indicators were consistently improving, but due to the COVID-19 pandemic the progress has halted, and health systems have been overburdened, shifting back the focus to major challenges and constraints in health systems - safety being one of them. COVID-19 pandemic has given boost for improvement of health care infrastructure as well as human resources development initiatives as being evident in Govt and Private sector.

COVID-19 first wave gave the experience of handling delicate health system, safety required for health care providers, patients, required PPEs and other necessary aspects and understanding mechanism for over saturated health system and triage mechanism for management and financial control while in the another surge of COVID-19 cases which may become second wave is giving lessons with respect to handling both COVID and non-COVID care, handling patients management with better protocols and same time how to increase capacity building inspite of higher case load in many locations then first wave and how to overcome vaccine hesitancy among health care providers, prioritising vaccination to health care professionals first, then population in various priority groups. These lessons and experiences will go a long way we provide safety culture system in health care delivery system.

Ergonomic safety: Importance and fundamentals

Safety culture is important in health care delivery systems to achieve the following by applying the appropriate design approach–

i) to accommodate the workforce at hospitals
ii) to increase their performance, effectiveness, and productivity
iii) to reduce errors and fatigue
iv) to minimize the risk by affective training and effective communication
v) to increase staff satisfaction, safety, and health, and
vi) to improve overall healthcare quality.

The fundamentals regarding safety culture in healthcare delivery system address the functional requirements of the healthcare workforce by asking the following six basic questions:

Who are at risk – The users (patients) and the providers (clinical and non-clinical staff) of healthcare delivery system are at risk?
What is the risk – It is important to understand the activities that the healthcare workers are doing (extreme work, average work, adjustable work) and under which hospital environment are they doing it. The needs must be addressed according to task analysis of the worker for functional, safety and security dimensions as an individual as well as the team and the patient's perspective.

How are they at risk – The activities performed by healthcare worker might be technical, non-technical, or administrative in a particular healthcare setting requiring specific functional design to support work– if not provided might put them at risk.

When are they at risk – When the healthcare worker engages in intense concentrated work for longer durations, patient/client interactions and emergencies they will be at risk?

Where are they at risk – Workplaces can be solo or dedicated workplaces, shared workplaces, and collaborative workplaces, for different purposes and functional requirements– each requiring special consideration while designing safety systems/norms for healthcare workers appropriate to accommodate all.

Why are they at risk – If SOPs, polices or guidelines for task to be performed and safety norms are not in place or not communicated or proper training has not been imparted or practiced by healthcare worker they will be at risk.

Ergonomic strategies for safety culture in Health care delivery system
Following are the ergonomic strategies for safety culture in healthcare delivery system–

i) **Fit workplace to the worker -** Working in a place where design is poor or hostile will decrease the performance of workers, increase errors, increase accidents and more fatigue due to inappropriate environment. Workplace should be adapted to worker and not vice versa by providing adjustable furniture, equipment, etc.
ii) **Proper assistance/support of work techniques and practices should be provided -** Support of work techniques and practices should be done

in the way they are performed to increase productivity and decrease accidents and fatigue by putting safety procedures in place. Proper assistance for safety procedures like entry/exit scheme (map) during fire outbreak or theft reporting and tracing protocols should be installed, practiced, and communicated at all levels of system.

iii) **Boost support for the primary task** – Enough support to perform the primary task must be provided.

iv) **Put emphasis on ease of use**.

v) **Offer appropriate user control -** Simple and easy to perform adjustment help worker control their workplace giving a sense of satisfaction and increased performance.

vi) **Provide for personalization of space** – Personalization of space helps the workers to fine tune preferences at individual as well as organizational level to improve the productivity and safety.

vii) **Train people in the proper use of equipment** – Healthcare workers must be demonstrated the techniques and benefits of appropriate adjustments to equipment/workplace to understand how and why to use it effectively and safely. Designs must be good/appropriate and have features which decrease the risk of hazard and injuries.

Build Safety Culture

A **Training Committee** needs to be formed which will also include members of safety committee who will be responsible for induction as well as regular trainings for safety culture at healthcare facility. A **need-based training** for skill development among healthcare workers will be a priority, for example – simple handwashing/sanitizing techniques during COVID-19 pandemic. There should be focus on training for awareness, continuous improvement, and possible interventions of safe practices among healthcare workers. **Create independents checks** (such as checklist for safety audits or record of safety incidents) regarding content of training, any deviation from safety norms and amendments done to correct lacunae and increase functionality. We can also utilise **Hospital Safety Index** which is a tool developed by PAHO and a group of Caribbean and Latin American experts, is being widely used by health authorities to gauge the probability that a hospital or health facility will continue to function in emergency situations.

Regular trainings, random checks and safety mock drills will ensure that the healthcare workers are following safety culture and that the patients will also benefit from the same; for example, imparting hands-on training for standard Bio-Medical Waste (BMW) management guidelines 2016 for handling BMW. The **Training Documentation and Monitoring systems** done at periodic intervals as well as randomly (without staff knowing), goes a long way in managing situations even in emergency response. **Correct Communication and soft skills** are of prime importance during disasters/panic situations. These regular training measures will help in identifying root cause for safety incidents, immediate corrective action, prevent future mishaps, and create a safe secure healthcare facility. Safety culture must be built upon transparent well communicated policies for both the patients and the healthcare workers. The security guidelines should support appropriate patient care and services in safe environment for provider as well.

Leading and supporting staff

Leadership plays an important role in health care system. Each health care providers at various levels should be equip with skill dot leadership roles in their own level and working system. The higher leadership at each level need to support them for their actions. All actions of the leaders at various levels comes with addition of the responsibility. The COVID-19 pandemic has shown how leadership has to play a role during the period of crisis and have balance system of leadership. There are various styles of leadership and each have their own advantages and dis-advantages and must respected. Leadership should have culture of obtaining feedback and opinion from all the stakeholders and decide appropriate decision based on best available evidence.

Promote Reporting, Learn and Share safety lessons

The risk management activities must function integrated way. The coherence of the above various risk management actions is required. The reporting of an event should be part of the culture of the organisation, and it should be promoted so that there is no hesitation and fear of reporting. The event should be audited by a team and necessary lessons learnt should be discussed with in audit committee, in the organisation and should be presented in international and national conferences and should be published and are available in the public domain. During disasters hospital and other health facilities are vital assets to communities. Safe hospitals guard patients, visitors, and staff and the investment in health infrastructure from risk/hazards.

Safe hospitals continue to function and offer life-saving medical care in adversities. Safe hospitals maintain the chain of storage and supply of vaccines, medicines, and other health care items. Assessment of the safety and preparedness of hospitals identifies priorities for remedial action, including cost-effective retorting. New hospitals are safeguarded by risk-sensitive setting, design and building in compliance with building codes. Emergency planning, staff training and exercises building hospital capacity to manage risks and reporting effectively. Health risks such as – traumatic injury and death due to structural collapse, disruption of health services, impeded emergency response and loss of economic investment due to destruction – need special mention. Health infrastructure should be self-sustainable and environment friendly in terms of electricity supply, water supply, waste disposal, etc.

Considerations in Risk Management

Health care facilities must be safer and prepared for emergencies by developing and implementing national level policies and programmes which facilitate safe health facilities in day-to-day life and in emergencies. Safe site should be selected for developing a healthcare facility. Healthcare facility design should be safe, and construction should be robust as well as in line with construction norms. Safety of existing health facility should be assessed on pre-decided parameters such as applying the Hospital Safety Index. Special consideration should be given to protecting healthcare workers, equipment, medicines, and other vital supplies. It must be ensured that health facilities receive essential services without delay and disruption. Community linkages and partnership have to be developed between health facilities and the community keeping the most vulnerable population in mind. The emergency risk management programs and response plans for healthcare facilities have to be developed. Regular testing, assessing, coordinating, and updating mitigation response plans with exercises should be incorporated and advocated with accountability. Training of healthcare workers to respond to emergencies is most vital. To enhance health system safety culture in disaster preparedness (such as COVID-19 pandemic) evaluating and learning lessons from past emergencies and disasters to 'Build Back Better' in recovery, rehabilitation and reconstruction is most effective.

Opportunities and Challenges in applying ergonomically Safe culture

Health care delivery system is unique setting, which is operational 24X7, 365 days, where staff works in common areas in shifts: dealing with patients from all age groups and settings. The safety, security, regulations, and privacy of both healthcare providers is as important as consumers. Health care systems are always under pressure to work more efficiently round the clock at a cost which is affordable and acceptable.

Ergonomically safe working environment will decrease the stress and fatigue of staff, thus increasing the effectiveness, in healthcare delivery, improve outcomes and quality of health care provided. Healthcare workers are expected to do multitasking along with applying their knowledge and skills. Healthcare workers involved in patient care are at risk of back strain, other Musculoskeletal

Disorder（MSDs） and work-related injuries from their work. Client/ Patient satisfaction and perception add to the psychosocial strains on the clinical as well as no-clinical staff. There is a research gap in understanding the causes, magnitude, and consequences of MSDs among healthcare workers, which needs to be addressed. A holistic multidimensional evidence-based preventive approach is required for addressing physical and psychosocial risk reduction among healthcare workers. This may be achieved by complimenting already existing patient safety programme with employee programmes. Ergonomically safe environment should be seen as an opportunity to reduce the work-related injuries and illness among the healthcare workforce, thus improving their efficiency, effectivity, productivity, and further boosting their morale. The challenges need to be appropriately converted into opportunities for the improvement of the health system.

Conclusion

Safety culture in health care delivery system is very important for not only health care professionals but also general populations. The evidence-based practices, planning, reporting system, security system, strategies should be in place. Awareness, training and implementation of these should be given utmost priority for the safety of everyone. The independent infection control, safety committee and risk assessment team should be in place and their suggestions and advise to considered very important for improvement of safety culture. Research involving the safety systems, risk assessment should be given utmost priority and has to be important aspect of agenda for the implementation of safety culture. Joint team efforts of Govt and private health care providers and scientific integration of concepts of health and wellness, modern medicine, indigenous health system, financial system including insurance mechanism, cyber security is required for appropriate safety of the health care delivery system.

Take home messages

1. Safety culture in health care delivery system is very important for not only health care professionals but also general populations.
2. The evidence based practices, planning, reporting system, security system, strategies should be in place.
3. Awareness, training and implementation of these should be given utmost priority for the safety of everyone.
4. The independent infection control, safety committee and risk assessment team should be in place and their suggestions and advise to considered very important for improvement of safety culture.
5. Research involving the safety systems, risk assessment should be given

utmost priority and has to be important aspect of agenda for the implementation of safety culture.

6. COVID–19 pandemic first wave and recent surge of cases in the form of probably second wave has opened up new dimension of the chapter safety, safety culture and these day to day evolving aspects should become part of culture of the health care delivery system.
7. Joint team efforts of Govt and private health care providers and scientific integration of concepts of health and wellness, modern medicine, indigenous health system, financial system including insurance mechanism, cyber security is required for appropriate safety of the health care delivery system.

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